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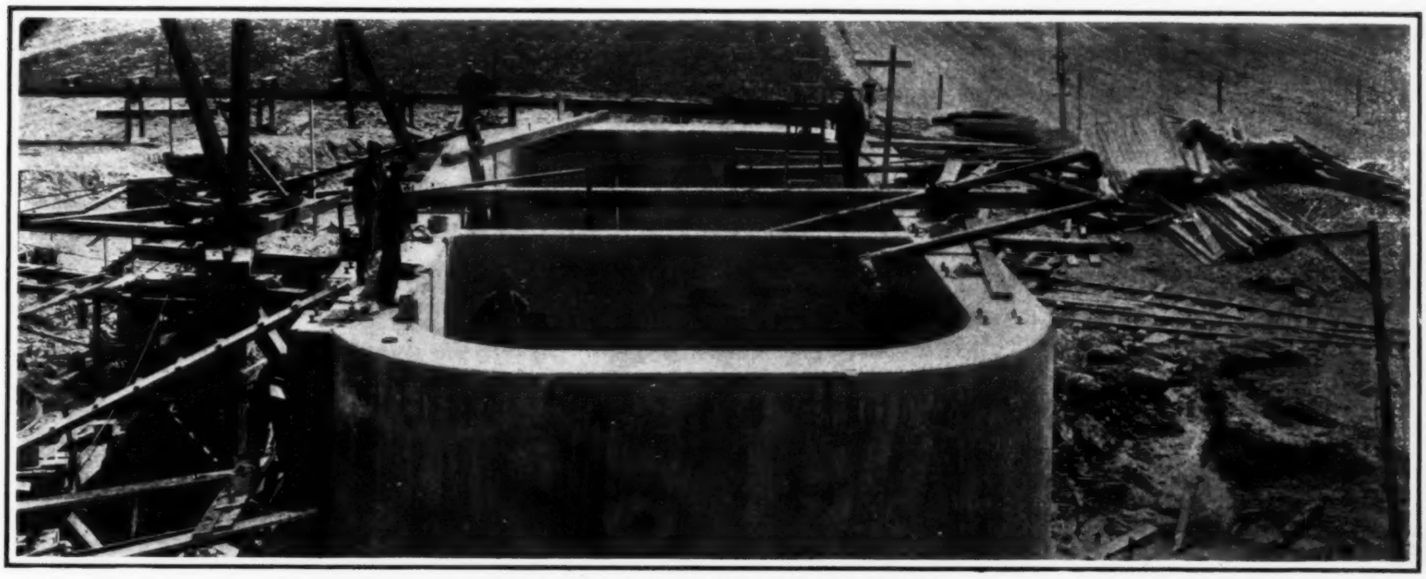


TOP OF SHAFT AS COMPLETED ABOVE THE SURFACE.

THE MIDDLE SHAFT, SHOWING METHOD OF STEEL REINFORCEMENT AND FORMATION OF MOLDS.

A CONCRETE COAL MINE SHAFT.—[See page 8.]

RAYS OF POSITIVE ELECTRICITY.*

A NEW INVESTIGATION OF GOLDSTEIN'S "CANAL RAYS."

BY SIR J. J. THOMSON.

IN 1886 Goldstein discovered that when the kathode in a discharge-tube is perforated, rays pass through the openings and produce luminosity in the gas behind the kathode; the color of the light depends on the gas with which the tube is filled, and coincides with the color of the velvety glow which occurs immediately in front of the kathode. The appearance of these rays is indicated in Fig. 1, the anode being to the left of the kathode KK. Since the rays appeared through the narrow channels in the kathode, Goldstein called them "Kanalstrahlen"; now that we know more about their nature, "positive rays" would, I think, be a more appropriate name. Goldstein showed that a magnetic force which would deflect kathode rays to a very considerable extent was quite without effect on the "Kanalstrahlen." By using intense magnetic fields, W. Wien showed that these rays could be deflected, and that the deflection was in the opposite direction to that of the kathode rays, indicating that these rays carry a positive charge of electricity. This was confirmed by measuring the electrical charge received by a vessel into which the rays passed through a small hole, and also by observing the direction in which they are deflected by an electric force. By measuring the deflections under magnetic and electric forces, Wien found by the usual methods the value of e/m and the velocity of the rays. He found for the maximum value of e/m the value of 10^4, which is the same as that for an atom of hydrogen in the electrolysis of solutions. A valuable summary of the properties of these rays is contained in a paper by Ewers ("Jahrbuch der Radio-aktivität," iii., p. 291, 1906).

As these rays seem the most promising subjects for investigating the nature of positive electricity, I have made a series of determinations of the values of e/m for positive rays under different conditions. The results of these I will now proceed to describe.

APPARATUS.

Screen Used to Detect the Rays.—The rays were detected and their position determined by the phosphorescence they produced on a screen at the end of the discharge-tube. A considerable number of substances were examined to find the one which would fluoresce most brightly under the action of the rays. As the result of these trials willemite was selected. This was ground to a very fine powder and dusted uniformly over a flat plate of glass. Considerable trouble was found in obtaining a suitable substance to make the powder adhere to the glass. All gums, etc., when bombarded by the rays are liable to give off gas; this renders them useless for work in vacuum-tubes. The method finally adopted was to smear a thin layer of "water-glass" (sodium silicate) over the glass plate, and then dust the powdered willemite over this layer and allow the water-glass to dry slowly before fastening the plate to the end of tube.

The form of tube adopted is shown in Fig. 2. A hole is bored through the kathode, and this hole leads to a very fine tube F. The bore of this tube is made as fine as possible, so as to get a small, well-defined fluorescent patch on the screen. These tubes were either carefully made glass tubes or else the hollow thin needles used for hypodermic injections, which I

FIG. 1.

find answer excellently for this purpose. After getting through the needle, the positive rays on their way down the tube pass between two parallel aluminium plates AA. These plates are vertical, so that when they are maintained at different potentials the rays are subject to a horizontal electric force, which produces a horizontal deflection of the patch of light on the screen. The part of the tube containing the parallel aluminium plates is narrowed as much as possible, and passes between the poles PP of a powerful electromagnet of the Du Bois type. The poles of this magnet are as close together as the glass tube will permit, and are arranged so that the lines of magnetic force are horizontal and at right angles to the path of the rays. The magnetic force produces a vertical deflection of the patch of phosphorescence on the screen. To bend the positive rays it is necessary to use strong magnetic fields, and if any of the lines of force were to stray into the discharge-tube in front of the kathode they would distort the discharge in that part of the tube. This distortion might affect the position of the phosphorescent patch on the screen, so that unless we shield the discharge tube

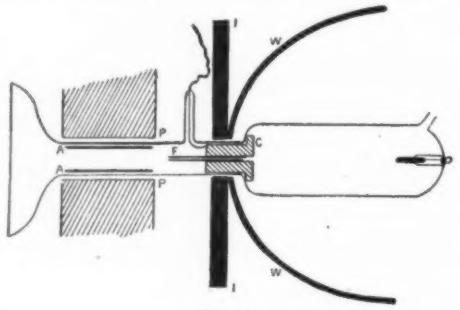


FIG. 2.

we cannot be sure that the displacement of the phosphorescence is entirely due to the electric and magnetic fields acting on the positive rays after they have emerged from behind the kathode.

To screen off the magnetic field the tube was placed in a soft iron vessel W with a hole knocked in the bottom, through which the part of the tube behind the kathode was pushed. Behind the vessel a thick plate of soft iron with a hold bored through it was placed, and behind this again as many thin plates of soft iron, such as are used for transformers, as there was room for, were packed. When this was done it was found that the magnet produced no perceptible effect on the discharge in front of the kathode.

The object of the experiments was to determine the value of e/m by observing the deflection produced by magnetic and electric fields. When the rays were undeflected they produced a bright spot on the screen; when the rays passed through electric and magnetic fields the spot was not simply deflected to another place, but was drawn out into bands or patches, sometimes covering a considerable area. To determine the velocity of the rays, and the value of e/m, it was necessary to have a record of the shape of these patches. This might have been done by substituting a photographic plate for the willemite screen. This, however, was not the method adopted, as, in addition to other inconveniences, it involves opening the tube and re-pumping for each observation, a procedure which would have involved a great expenditure of time. The method actually adopted was as follows: The tube was placed in a dark room from which all light was carefully excluded, the tube itself being painted over, so that no light escaped from it. In these circumstances the phosphorescence on the screen appeared bright and its boundaries well defined. The observer traced in India ink on the outside of the thin flat screen the outline of the phosphorescence. When this had been satisfactorily accomplished the discharge was stopped, the light admitted into the room, and the pattern on the screen transferred to tracing-paper. The deviations were then measured on these tracings.

CALCULATION OF THE MAGNETIC AND ELECTRIC DEVIATION OF THE RAYS.

If we assume the electric field to be uniform between the plates and zero outside them, then we can easily show that x, the horizontal deflection of a ray the charge of which is e, mass m, and velocity v, is given by the equation

$$x = \tfrac{1}{2} X \frac{e}{mv^2} l\,(l + 2d)$$

where X is the force between the plates, l the length of path of the rays between the plates, and d the distance of the screen from the nearer end of the parallel plates.

To find the deflection due to the magnetic field, we have, if p is the radius of curvature of the path at a point where the magnetic force is H,

$$\frac{mv^2}{p} = Hev$$

or

$$\frac{1}{p} = \frac{e}{mv} H$$

If y is the vertical displacement of the particle, we have

$$\frac{1}{p} = \frac{d^2y}{dz^2} \text{ approximately}$$

where z is measured along the path of the ray. Hence

$$\frac{d^2y}{dz^2} = \frac{e}{mv} H;$$

$$y = \frac{e}{mv}\left[\int_0^{l+d}\int_0^z H\,dz\right] \quad . \quad . \quad . \quad . \quad (1)$$

In these strong fields there are considerable variations of H along the path, so that to calculate the integrals we should have to map out the value of H along the path of the ray. This would be a very laborious process, and it was rendered unnecessary by the following simple method, which, while not involving anything like the labor of the direct method, gives much more accurate results. The method is shown in Fig. 3. The part of the tube through which the rays pass was cut off, and a metal rod placed so that its tip Z coincided with the aperture of the narrow tube through which the positive rays had emerged. A very fine wire soldered to the end of this tube passed over a light pulley, and carried a weight at the free end. The pulley was supported by a screw, by means of which it could be raised or lowered; a known current passed through the wire, entering it at Z and leaving it through the pulley. The pulley was first placed so that the path of the stretched wire when undeflected by a magnetic field coincided with the path of the undeflected rays. A vertical scale, the edge of which was at the same distance from the opening through which the rays emerge as the screen on which the phosphorescence had been observed, was placed just behind the wire, and was read by a reading microscope with a micrometer eyepiece. When the magnetic field was put on, the wire was deflected; and if T is the tension of the wire, p the radius or curvature into which it is bent, i the current through the wire,

$$\frac{T}{p} = Hi;$$

or, if y_1 is the vertical displacement of the wire,

$$\frac{d^2y_1}{dz^2} = \frac{i}{T} . H$$

Now if $\dfrac{dy_1}{dz} = 0$ when $z = 0$ we have, if y_1 is the displacement of the wire at the scale,

$$y_1 = \frac{i}{T}\int_0^l \cdot \int_0^z H\,dz. \quad . \quad . \quad . \quad (2)$$

Hence, comparing (1) and (2) we have

$$\frac{y}{y_1} = \frac{\dfrac{e}{mv}}{\dfrac{i}{T}} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (3)$$

a relation from which the magnetic force is eliminated. To insure that the tangent to the wire is

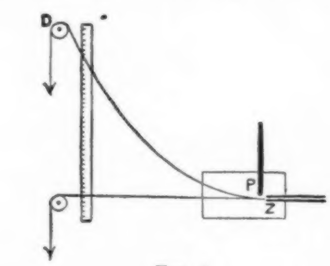


FIG. 3.

horizontal when $z = 0$, the following method is used: P is a chisel-edge carried by a screw and placed about 1 millimeter in front of the fixed end of the wire; this is adjusted so that when the magnetic field is not on, the wire just touches the edge; this can be ascertained by making the contact with the wire complete an electric circuit in which a bell is placed. When the magnetic field is put on the wire is pulled off from the edge, and the tangent at $z = 0$ is no longer horizontal; it can, however, be brought horizontal by raising or lowering the pulley D until the wire is again in contact with P, which can be ascertained again by the ringing of the bell. Then y_1 is the ver-

* Discourse delivered at the Royal Institution by Sir J. J. Thomson, F.R.S.

tical distance between the point where the wire now crosses the edge of the scale and the point where it crossed it before the magnetic field was put on. Since y, y_1, i, and T can easily be measured, equation (3) gives us the value of e/mv, while the deflection under the electric force gives the value of e/mv_2.

If y is the vertical displacement of the patch of phosphorescent light on the screen produced by the magnetic field, x the horizontal displacement due to the electrostatic field, we see that

$$y = \frac{y_1}{\left(\frac{i}{T}\right)^2}\frac{e}{mv} = B\frac{e}{mv}$$

$$x = A\frac{e}{mv^2}$$

where A and B are constants depending on the position of the screen and the magnitudes of the electric

FIG. 4.

FIG. 5.

and magnetic forces. These quantities can be calculated by means of the equations just given.

Since

$$\frac{v}{x} = \frac{B}{A}$$

$$\frac{y^2}{x} = \frac{B^2 m}{A e}$$

We see that if the pencil is made up of rays having a constant velocity, but having all values of e/m up to a maximum value, the spot of light will be spread out by the magnetic and electric fields into a straight line extending a finite distance from the origin. While if it is made up of two sets of rays, one having the velocity v_1, the other the velocity v_2, the spot will be drawn out into two straight lines as in Fig. 4.

If e/m is constant and the velocities have all values up to a maximum, the spot of light will be spread out into a portion of a parabola as indicated in Fig. 5.

We shall later on give examples of each of these cases.

The discharge was produced by means of a large induction coil, giving a spark of about 50 centimeters in air, with a vibrating make and break apparatus. Many tubes were used in the course of the investigation; the dimensions of these varied slightly. The distance of the screen from the hole from which the rays emerged was about 9 centimeters, the length of the parallel plates about 3 centimeters, and the distance between them 0.3 centimeter.

PROPERTIES OF THE POSITIVE RAYS WHEN THE PRESSURE IS NOT EXCEEDINGLY LOW.

The appearance of the phosphorescent patch after deflection in the electric and magnetic fields depends greatly upon the pressure of the gas. I will begin by considering the case when the pressure is comparatively high, say of the order of 1/50 millimeter. At these pressures, though the walls of the tube in front of the kathode were covered with bright phosphorescence and the dark space extended right up to the walls of the tube, and was several centimeters thick, traces of the positive column could be detected in the neighborhood of the anode. I will first take the case where the tube was filled with air. Special pre-

FIG. 6.

cautions were taken to free the air from hydrogen; it was carefully dried, and a subsidiary discharge-tube, having a kathode made of the liquid alloy of sodium and potassium, was fused on to the main tube. When the discharge passes from such a kathode it absorbs hydrogen. The discharge was sent through this tube at the lowest pressure at which enough light was produced in the gas to give a visible spectrum, until the hydrogen lines disappeared and the only lines visible were those of nitrogen and mercury vapor. This pressure was a little higher than that used for the investigation of the positive rays, but a pump or two was sufficient to bring the pressure down to this value. The appearance of the phosphorescence on the screen when the rays were deflected by magnetic and electric forces separately and conjointly is shown in Fig. 6.

The deflection under magnetic force alone is indicated by vertical shading, under electric force alone by horizontal shading, and under the two combined by cross shading.

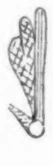
The spot of phosphorescence is drawn out into a band on either side of its original position. The upper portion, which is very much the brighter, is deflected in the direction which indicates that the phosphorescence is produced by rays having a positive charge; the lower portion (indicated by dots in the figure), which though faint is quite perceptible on the willemite screen, is deflected as if *the rays carried a negative charge.* The length of the lower portion is somewhat shorter than that of the upper one, but is quite comparable with it. The intensity of the luminosity in the upper portion is at these pressures quite continuous; no abrupt variations such as would show themselves as bright patches could be detected, although, as will be seen later on, these make their appearance at lower pressures. Considering for the present the upper portion, the straightness of the edges shows that the velocity of the rays is approximately constant, while the values of e/m range from zero at the undeflected portion to the value approximately equal to 10^4 at the top of the deflected band. This value of e/m is equal to that for a charged hydrogen atom, and, moreover, there was no specially great luminosity in the positions corresponding to $e/m = 10^4/14$ and $10^4/16$, the values for rays carried by nitrogen or oxygen atoms, though these places were carefully scrutinized. As hydrogen when present as an impurity in the tube has a tendency to accumulate near the kathode, the following experiment was tried to see whether the Kanalstrahlen were produced from traces of hydrogen in the tube. The discharge was sent through the tube in the opposite direction, that is, so that the perforated electrode was the anode, the electric and magnetic fields being kept on. When the discharge passed in this way there was, of course, no luminosity on the screen; on reversing the coil again, so that the perforated electrode was the kathode, the luminosity flashed out instantly, presenting exactly the same appearance as it had done when the tube had been running for some time with the perforated electrode as kathode.

The fact that a spot of light produced by the undeflected positive rays is, under the action of electric and magnetic forces, drawn out into a continuous band was observed by W. Wien, who was the first to measure the deflection of the positive rays under electric and magnetic forces. The values of e/m obtained from the deflections of various parts of this band range continuously from zero, the value corresponding to the undeflected portion, to 10^4, the value corresponding to those most deflected. Wien explained this by the hypothesis that the charged particles which make up the positive rays act as nuclei, round which molecules of the gas through which the rays pass condense, so that very complex systems made up of a very large number of molecules get mixed up with the particles forming the positive rays, and that it is these heavy and cumbrous systems which give rise to that part of the luminosity which is only slightly deflected. I think that the constancy of the velocity of the rays, indicated by the straight edges of the deflected band, is a strong argument against this explanation, and that the existence of the negative rays is conclusive against it. These negatively electrified rays, which form the faintly luminous portion of the phosphorescence indicated in Fig. 6, are not kathode rays. The magnitude of their deflection shows that the ratio of e/m for these rays, instead of being as great as 1.7×10^7, the value for kathode rays, is less than 10^4. The particles forming these rays are thus comparable in size with those which form the positive rays. The existence of these negatively electrified rays suggests at once an explanation, which I think is the true one, of the continuous band into which the spot of phosphorescence is drawn out by the electric and magnetic fields. The values of e/m which are determined by this method are really the mean values of e/m, while the particle is in the electric and magnetic fields. If the particles are for a part of their course through these fields without charge, they will not during this part of their course be deflected, and in consequence the deflections observed on the screen, and consequently the values of e/m, will be smaller than if the particle had retained its charge during the whole of its career. Thus, suppose that some of the particles constituting the positive rays, after starting with a positive charge, get this charge neutralized by attracting to them a negatively electrified corpuscle, the mass of the corpuscle is so small in comparison with that of the particle constituting the positive ray that the addition of the particle will not appreciably diminish the velocity of the positive particle. Some of these neutralized particles may get positively ionized again by collision, while others may get a negative charge by the adhesion to them of another corpuscle, and this process might be repeated during the course of the particle. Thus there would be among the rays some which were for part of their course unelectrified, at other parts positively electrified, and at other parts negatively electrified. Thus the mean value of e/m might have all values ranging from a, its initial value, to $-a'$, where a' might be only a little less than a. This is just what we observe, and when we remember that the gas through which the rays are passing is ionized, and contains a large number of corpuscles, it is, I think, what we should expect.

At very low pressures, when there are very few ions in the gas, this continuous band stretching from the origin is replaced by discontinuous patches.

POSITIVE RAYS IN HYDROGEN.

In hydrogen, when the pressure is not too low, the



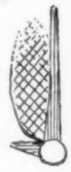


FIG. 8. FIG. 7. FIG. 9.

brightness of the phosphorescent patch is greater than in air at the same pressure; the shape of the deflected phosphorescence is markedly different from that in air. In air, the deflected phosphorescence is usually a straight band, whereas in hydrogen the boundary of the most deflected side is distinctly curved and is concave to the undeflected position. The appearance of the deflected phosphorescence is indicated in Fig. 7.

The result indicated in Fig. 8, which was also obtained with hydrogen, shows that we have here a mixture of two bands, as indicated in Fig. 4, the two bands being produced by carriers having different maximum values of e/m. The greatest value of e/m obtained with hydrogen was the same as in air, 1.2×10^4, the velocity was 1.8×10^8 centimeters per second. The presence of the second band indicates that mixed with these we have another set of carriers, for which the maximum value e/m is half that in the other band, that is, 5×10^3. The curvature of the boundary generally observed is due to the admixture of these two rays.

POSITIVE RAYS IN HELIUM.

In helium the phosphorescence is bright, and the deflected patch has in general the curved outline observed in hydrogen. I was fortunate enough, however, to find a stage in which the deflected patch was split up into two distinct bands, as shown in Fig. 9. The maximum value of e/m in the band a was 1.2×10^4, the same as in air and hydrogen, and the velocity was 1.8×10^8, while the maximum value of e/m in band b was almost exactly one quarter of that in a (that is, 2.9×10^3). As the atomic weight of helium is four times that of hydrogen, this result indicates that the carriers which produce the band b are atoms of helium. This result is interesting, because it is the only case (apart from hydrogen), in which I have found values of e/m corresponding to the atomic weight of the gas; and even in the case of helium, when the pressure in the discharge-tube is very low and the electric field very intense, the characteristic rays with $e/m = 2.0 \times 10^3$ sometimes disappear, and, as in all the gases I have tried, we get two sets of rays, for one set of which $e/m = 10^4$ and for the other 5×10^3.

Although the helium had been carefully purified from hydrogen, the band a (for which $e/m = 10^4$) was generally the brighter of the two. The case of helium is an interesting one; for the class of positive rays, known as the a rays, which are given off by radio-

Hydrogen

FIG. 10.

Helium

FIG. 11.

Air

FIG. 12.

active substances, would *a priori* seem to consist most probably of helium, since helium is one of the products of disintegration of these substances. The value of e/m for these substances is 5×10^3, where we have seen that in helium it is possible to obtain rays for which $e/m = 2.0 \times 10^3$. It is true that, at very low pressures and with strong electric fields, we get rays for which $e/m = 5 \times 10^3$; but this is not a peculiarity of helium; all the gases which I have tried show exactly the same effect.

ARGON.

When the discharge passed through argon, the effects observed were very similar to those occurring

in air. The sides were perhaps a little more curved, and there was a tendency for bright spots to develop. The measurements of the electric and magnetic deflection of these spots gave $e/m = 10^4$, the value obtained for other cases. There was no appreciable increase of luminosity in the positions corresponding to $e/m = 10^4/40$, as there would have been if an appreciable number of the carriers had been argon atoms.

POSITIVE RAYS IN GASES AT VERY LOW PRESSURES.

As the pressure of the gas in the discharge-tube is gradually reduced, the appearance of the deflected phosphorescence changes; instead of forming a continuous band, the phosphorescence breaks up into two isolated patches, that part of the phosphorescence in which the deflection was very small disappears, as also does the phosphorescence produced by the negatively electrified portion of the rays.

In the earlier experiments considerable difficulty was experienced in working at these very low pressures; for when the pressure was reduced sufficiently to get the effects just described, the discharge passed through the tube with such difficulty that in a very few seconds after this stage was reached sparks passed from the inside to the outside of the tube, perforating the glass and destroying the vacuum. In spite of all precautions, such as earthing the kathode and all conductors in its neighborhood, perforation took place too quickly to permit measurements of the deflection of the phosphorescence.

This difficulty was overcome by taking advantage of the fact that, when the kathode is made of a very electro-positive metal, the discharge passes with much greater ease than when the kathode is made of aluminium or platinum. The electropositive metals used for the kathode were: (1) the liquid alloy of sodium and potassium, which was smeared over the kathode, and (2) calcium, a thin plate of which was affixed to the front of the kathode. With these kathodes, the pressure in the tube could be reduced to very low values without making the discharge so difficult as to lead to perforation of the tube by sparking, and accurate measurements of the position of the patches of phosphorescence could be obtained at leisure.

The results obtained at these low pressures are very interesting. Whatever kind of gas may be used to fill the tube, or whatever the nature of the electrode, the deflected phosphorescence splits up into two patches. For one of these patches the maximum value of e/m is about 10^4, the value for the hydrogen atom; while the value for the other patch is about 5×10^3, the value for a particles or the hydrogen molecule. Examples of the appearance of this phosphorescence are given in Figs. 10, 11, and 12. In Fig. 12 the magnetic force was reversed.

The differences in the appearance are due to differences in the pressure rather than to differences in the gas; for at slightly higher pressure than that corresponding to Fig. 12, the appearance shown in Figs. 10 and 11 can be obtained in air. In all these cases the more deflected patch corresponds to a value of about 10^4 for e/m, while e/m for the less deflected patch is about 5×10^3.

It will be noticed that in Fig. 11 there is no trace in the helium tube of rays for which $e/m = 2.5 \times 10^3$, which were found in helium tubes at higher pressures; at intermediate pressures there are *three* distinct patches of helium, for the first of which $e/m = 10^4$, for the second $e/m = 5 \times 10^3$, and for the third $e/m = 2.5 \times 10^3$ approximately. Helium is a case where there are characteristic rays, that is, rays for which $e/m = 10^4/M$, where M is the atomic weight of the gas, when the discharge potential is comparatively small, and not when, as at very low pressures, the discharge potential is very large. I think it very probable that, if we could produce the positive rays with much smaller potential differences than those used in these experiments, we might get the characteristic rays for other gases. I am at present investigating with this object the positive rays produced when the perforated kathode is, as in Wehnelt's method, coated with lime, when a potential difference of 100 volts or less is able to produce positive rays. The interest of the experiments at very low pressures lies in the fact that in this case the rays are the same whatever the gas may be used to fill the tube; the characteristic rays of the gas disappear, and we get the same kind of carriers for all substances.

I would especially direct attention to the simplicity of the effect produced at these low pressures; only two patches of phosphorescence are visible. This is, I think, an important matter in connection with the interpretation of these results; for at these low pressures we have to deal, not only with the gas with which the tube was originally filled, but also with the gas which is given off by the electrodes and the walls of the tube during the discharge; and it might be urged that at these low pressures the tube contained nothing but hydrogen given out by the electrodes. I do not think this explanation is feasible, for the following reasons:

(1) The gas developed during the discharge is not wholly hydrogen; if the discharge is kept passing long enough to develop so much gas that the discharge through the gas is sufficiently luminous to be observed by a spectroscope, the spectrum always showed, in addition to the hydrogen lines, the nitrogen bands; indeed, the latter were generally the most conspicuous part of the spectrum. If the phosphorescent screen on which the positive rays impinge is observed during the time this is being given off, the changes which take place in the appearance of the screen are as follows: If, to begin with, the pressure is so slow that the phosphorescent patches are reduced to two bright spots, then, as the pressure begins to go up owing to the evolution of the gas, the deflection of the spots increases. This is owing to the reduction in the velocity of the rays consequent upon the reduction of the potential difference between the terminals of the tube, as at this stage an increase in the pressure facilitates the passage of the discharge. In addition to the increase in the displacement there is an increase in the area of the spots giving a greater range of values of e/m; this is owing to the increase in the number of collisions made by the particles in the rays on their way to the screen. As more and more gas is evolved the patches get larger, and finally overlap; the existence of the second patch being indicated by a diminution in the brightness of the phosphorescence at places outside its boundary. As the pressure increases the luminosity gets more and more continuous, and we finally get to the continuous band, as shown in Fig. 6. At this stage it is probable that there may be enough luminosity to give a spectrum showing the nitrogen lines, indicating that a considerable part of the gas in the tube is air. It is especially to be noted that during this process, when gas was coming into the tube, there has been no development of patches in the phosphorescence indicating the presence of new rays; on the contrary, one type of carrier—that corresponding to $e/m = 5 \times 10^3$—has disappeared. The presence of the nitrogen bands in the spectrum shows that nitrogen is carrying part of the discharge, and yet there are no rays characteristic of nitrogen to be observed on the screen, a proof, it seems to me, that different gases may be made by strong electric fields to give off the same kind of carriers of positive electricity.

Another result, which shows that the positive rays are the same although the gases are different, is the following: The tube was pumped until the pressure was much too low for the discharge to pass, then small quantities of the following gases were put into the tube: air, carbonic oxide, hydrogen, helium, neon (for which I am indebted to the kindness of Sir James Dewar); the quantity admitted was adjusted so that it was sufficient to cause the discharge to pass, and yet did not raise the pressure beyond the point where the phosphorescence is discontinuous. In every case there were patches corresponding to $e/m = 10^4$, $e/m = 5 \times 10^3$, and except with helium these were the only patches; in helium, in addition to the two already mentioned, there was a third patch, for which $e/m = 2.5 \times 10^3$.

I also tried another method of insuring that at these low pressures there were other gases besides hydrogen in the tube. I filled the tube with helium, and after exhausting to a fairly low pressure by means of the mercury pump, I performed the last stages of the exhaustion by means of charcoal cooled with liquid air. This charcoal absorbs very little helium in comparison with other gases, so that it is certain that there was helium in the tube. The appearance on the phosphorescent screen of tubes exhausted in this way did not differ from those exhausted solely by the pump.

The most obvious explanation of these effects seems to me to be that under very intense electric fields different substances give out particles charged with positive electricity, and that these particles are independent of the nature of the gas from which they originate. These particles are, so far as we know at present, of two kinds; for one kind e/m has the value of 10^4, that of an atom of hydrogen; for the other kind e/m has half this value, that is, it has the same value as for the a particles from radio-active substances.

This agreement in the maximum value of e/m at different pressures is a proof that this is a true maximum, and that there are not other more deflected rays not strong enough to produce visible phosphorescence; for if this were the case, that is, if the value of e/m for a particle that had never lost its charge temporarily by collision were greater than 10^4, we should expect to get larger values for e/m at low pressures than at high.

A NEW METHOD IN REINFORCED CONCRETE FLOORING.

A NEW sectional concrete flooring has recently been invented by Herr Thrul, city engineer of Vienna. The floor is built of single beams, set closely together. These beams consist of a curved upper segment whose ends are connected by a chord (Fig. 1). Both parts work against compression and tension stresses, the tension being taken up by reinforcements in the chord and the compression by the reinforcement in the segment. The beams show very large hollows, lightening the weight of the floor and allowing ventilation between ceiling and floor. The use of this flooring which is prepared away from the building and delivered ready for use does away with need of framework or centering, so allowing of quicker construction. It is light and easy to handle, and costs little to make. If a building is destroyed, the flooring may be used again.

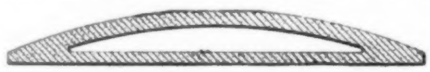


FIG. 1.

Loading tests give satisfactory results. A floor of 9 feet 10 inches span, constructed of three single beams 8 inches wide, having a loading surface of 6.14 square feet, calculated to support a load of 550 pounds, showed the first cracks under a load of 7,110 pounds, and only under a load of 9,770 pounds larger cracks appeared upon the chord, where the segment rose. Under a load of 13,717 pounds the test floor gave way, after having supported this load for three and one-fourth hours. The floor withstood therefore without strain a ten times greater load than it was calculated for. The bending of the segment in the middle was only 1/25 of an inch. A second test floor, with a span of 19.8 feet, also consisting of three beams, was loaded with 12,372 pounds and this load left for twenty-four hours. After this time the floor did not show any sign of weakening, and no cracks were visible, although it was calculated to support only a load of 550 pounds. The first fine air cracks appeared under a load of 18,977 pounds, also an increasing inward flexion. After thirty minutes the floor collapsed. The loaded surface was 12,276 square feet.

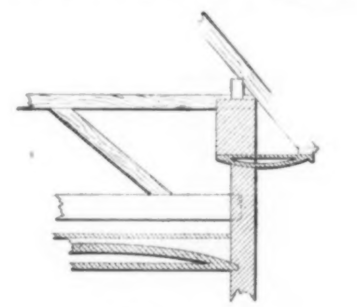


FIG. 2.

Fig. 2 shows the Thrul beam used as overhang for a roof. These beams have been extensively used in Austria for bridges, and heavy floor constructions.—Abstracted from Zement und Beton.

ILLUMINATED STREET SWEEPERS.

ELECTRICALLY lighted "white wings" is one of the newest innovations, and has proved so satisfactory that it is predicted the system will become popular in all cities where men are employed at night for keeping the streets clean. The South Park Board of Commissioners, Chicago, Ill., employs a number of street cleaners at night on Michigan Avenue between Jackson Boulevard and Twelfth Street, and on Jackson Boulevard between Michigan Avenue and the river. These streets are the prominent down-town driveways for carriages and automobiles. The commissioners found that the work of cleaning streets at night was hampered and the lives of the members of the "white wing" squad endangered by the automobiles and coupés which use these driveways. To make the work of street cleaning less hazardous Mr. H. S. Richards, assistant superintendent of the South Park Board, devised a plan whereby the men could, without difficulty, carry a signal lamp that would clearly mark their presence at any point on the driveways. The batteries used in the man-lighting scheme are of the 2-volt, 6-ampere type and are designed to burn continuously 10 hours, after which they are recharged. Small tungsten lamps are used. The combined weight of the outfit is about three-quarters of a pound. The battery fits into the hip pocket of the sweeper's trousers. The leads run from the battery under the man's coat to the lamp, which is attached to his helmet. The battery is connected up when the man goes to work at night and is left connected until he quits work in the morning. It was originally planned to use red lamps on the helmet, but the clear white lamp was substituted because it could be seen from a greater distance. The plan has worked so well it is announced that it will be permanently adopted by the commission for the use of the night squad employed on streets where their work is hampered by vehicles.—Electrical World.

AERIAL LOCOMOTION IN WARFARE.*

THE MILITARY POSSIBILITIES OF THE AEROPLANE AND AIRSHIP.

BY MAJOR GEORGE O. SQUIER, U. S. SIGNAL CORPS

WHATEVER may be the influence of aerial navigation upon the art of war, the fact which must be considered at present is, that each of the principal military powers is displaying feverish activity in developing this auxiliary as an adjunct to the military establishment.

If each of the great powers of the world would agree that aerial warfare should not be carried on, the subject would be of no great interest to this country as far as our military policy is concerned, but until such an agreement is made this country is forced to an immediate and serious consideration of this subject in order to be prepared for any eventuality.

The identical reasoning which has led to the adoption of a policy of providing for increasing our navy year by year to maintain our relative supremacy on the sea, is immediately applicable to the military control of the air. If the policy in respect to the navy is admitted, there is no escape from the deduction that we should proceed in the development of ships of the air on a scale commensurate with the position of the nation.

The question as to whether or not the powers will ultimately permit the use of aerial ships in war is not at present the practical one, because in case such use is authorized it will be too late adequately to equip ourselves after war has been declared.

ACTION OF THE HAGUE PEACE CONFERENCE.

The following is the declaration signed by the delegates of the United States to the Second International Peace Conference held at The Hague, June 15 to October 19, 1907, prohibiting the discharge of projectiles and explosives from balloons, ratified March 10, 1908.

Declaration:

The contracting powers agree to prohibit, for a period extending to the close of the Third Peace Conference, the discharge of projectiles and explosives from balloons or by other new methods of a similar nature.

The delegates of the United States signed this declaration. The countries which did not sign the declaration forbidding the launching of projectiles and explosives from balloons were: Germany, Austria-Hungary, China, Denmark, Ecuador, Spain, France, Great Britain, Guatemala, Italy, Japan, Mexico, Montenegro, Nicaragua, Paraguay, Roumania, Russia, Servia, Sweden, Switzerland, Turkey, Venezuela.

It appears that the United States is the only first-class power who signed this agreement, and an analysis of the text of the agreement itself shows that no serious attempt was made to settle the question finally.

For instance, while the war balloon may not discharge projectiles or explosives from above, yet no reciprocal provision is made preventing such war balloon from being fired upon from the earth below, yet the law of self-defense evidently obtains.

Furthermore, naval experts will tell you that they fear no enemy quite as much as a submarine mine, whose location is unknown and which gives no warning when it is approached. Our own experience shows that the battleship "Maine" could be completely destroyed in time of peace without any one detecting the preparations for its accomplishment.

If, then, a nation can submerge a mine for the destruction of ships from underneath the water, why can it not drop an aerial mine upon a ship from above? And if it should be allowed to drop an aerial mine upon an enemy's fortified ship at sea, it certainly should be allowed to drop such an aerial mine upon a fortified place on land.

INFLUENCE ON THE MILITARY ART.

The military art up to the present time has been practically conducted in a plane where the armies concerned have been limited in their movements in time and place by the physical character of the terrane. A large army, for instance, cannot move faster than about 12 miles a day by marching, and the use of railroads as applied to the art of war was first recognized in the Franco-German war. By their use, the mobilization of the great German army, and its accurate assembling in the theater of operations within ten days, contributed an initial advantage not before possible.

The very essence of strategy is surprise, and there never were better opportunities than at present for a constructive general to achieve great victories. But these victories to be really great, must be founded upon some new development or use of power not heretofore known in war. They must also tend to produce results with the minimum loss of human life. In other words, the sentiment of the world demands that the military art shall always aim to capture, not destroy.

It may be said that the consummation of military art is found in maneuvering the enemy into untenable situations, thereby forcing a decisive result with a minimum loss of life and treasure.

As to the technical use of dirigible balloons and aeroplanes in warfare we have nothing but theory at present to guide us. It would appear, however, in the case of dirigible balloons that two different classes of such ships should be developed.

First.—A comparatively small dirigible type with a capacity of from 50,000 to 100,000 cubic feet, to be used principally for scouting purposes and to a limited extent for carrying explosives for demolition or for incendiary purposes, such as destroying bridges and supply depots close to the mobile army or coast defense fortress. In reconnoitering dirigibles of this class, in order to be safe during day-time they will have to maneuver at an altitude of about a mile, but experiments show that telephotographic apparatus will operate from this height to give much detail.

At night such dirigibles may descend to within a few hundred feet of the ground with safety and thus obtain much valuable information. Equipped with wireless telegraph or telephone apparatus, military data could be obtained and transmitted without undue risk. Due to the small carrying capacity of such sizes, the radius of action would probably be limited at present to about two hundred miles.

Second.—This type of dirigible may be developed for burden-bearing purposes. It has been pointed out above that the larger the airship the greater the speed it may be given, and the greater its radius of action. There is no reason to doubt that airships of capacity from 500,000 to 1,000,000 cubic feet may be ultimately developed to attain speeds of 50 to 75 miles per hour. With a capacity for such speed, the aerial craft becomes a powerful practical engine of war which may be used in all ordinary weather. By keeping high in the air in day-time, and descending at night, they may launch high explosives, producing great damage. Being able to pass over armies and proceed at great speeds, their objectives would not usually be the enemy's armies, but their efforts would be directed against his base of supplies; to destroy his drydocks, arsenals, ammunition depots, principal railway centers, storehouses, and indeed the enemy's navy itself.

It is thought that there will be little difficulty in launching explosives with accuracy, provided good maps and plans are available. Due to the small cost of such ships as compared with naval vessels, the risk of loss would be readily taken.

The element of time has always been a controlling factor in warfare. It is often a military necessity to conduct a reconnoissance in force to develop the enemy's dispositions. This requires at times a detachment of several thousand men from the main army, for a considerable period of time to accomplish this end. With efficient military airships, these results may be attained with a very few men in a small fraction of the time heretofore required.

Delimitation of Frontiers.—The realization of aerial navigation for military purposes, brings forward new questions regarding the limitation of frontiers. As long as military operations are confined to the surface of the earth, it has been the custom to protect the geographical limits of a country by ample preparations in time of peace, such as a line of fortresses properly garrisoned. At the outbreak of war these boundaries represent real and definite limits to military operations. Excursions into the enemy's territory usually require the backing of a strong military force. Under the new conditions, however, these geographic boundaries no longer offer the same definite limits to military movements. With a third dimension added to the theater of operations, it will be possible to pass over this boundary on rapid raids for obtaining information, accomplishing demolitions, etc., returning to safe harbors in a minimum time. We may, therefore, regard the advent of military ships of the air as, in a measure, obliterating present national frontiers in conducting military operations.

One of the military objectives in warfare is usually the enemy's capital city, his ministers, and his chief executive. This objective has heretofore been protected by large armies of soldiers, who in themselves are not so important to the result. In order to attain the objective, it has been frequently necessary to subdue large numbers of soldiers needlessly.

With the advent of efficient ships of the air, however, small parties may pass over these protective armies on expeditions aimed at the seat of government itself, where reside the body of particular individuals most responsible, so that the ultimate result will be to deter a rash entrance into war for personal ends; since now for the first time responsible individuals of state may be in immediate and personal danger after the declaration of war, which heretofore has not been usually the case.

INTERIOR HARBORS.

In the development of these larger types of dirigible balloons the main difficulty will be in providing suitable harbors or places of safety, for replenishing supplies and for seeking shelter in times of stress. As long as the dirigible balloon remains in the air it may be regarded as tolerably safe, both in itself, and as a conveyance for observers. If its engines are disabled, it is at least a free balloon and may be operated as such.

When brought in contact with the ground, however, it is in considerable danger from high winds. The momentum of such an enormous airship is great, and the comparatively fragile structure of the craft makes it an easy prey to the pounding which it is likely to receive when landing. Just as marine ships must seek a sheltered harbor or put to the open sea in times of storm, so in case of ships of the air, it is much more necessary either to brave the storm in the open, or to seek some sheltered harbor on land.

Fortunately, in this case, certain suitable harbors for very large ships may be provided at small expense, by using narrow and deep valleys and ravines, surrounded by forests or other protection, or prepared railway cuts, etc., where the airship may descend and be reasonably safe from the winds above. These harbors should, of course, be known to the pilot, and carefully plotted on his maps beforehand. The compass bearings of each harbor from prominent points on land must be known and plotted, to assist as far as possible in navigating the airship in thick weather; and such harbors may be indicated to the pilot at night by vertical searchlight beams, or by suitable rockets, etc.

The aeroplane, as has been pointed out, is likely to prove a flying machine of comparatively low tonnage and high speed. It is not likely to become a burden-bearing ship, at least in single units, but will be extremely useful for reconnoitering purposes; for dispatching important orders and instructions at high speed; for reaching inaccessible points; or for carrying individuals of high rank and command to points where their personality is needed.

One of the bloodiest contests the world has ever seen was the Japanese attack on "203 Meter Hill," yet the sole object of this great slaughter was for the purpose of placing two or three men at its summit to direct the fire of the Japanese siege guns upon the Russian fleet in the harbor of Port Arthur.

If the United States had possessed in 1898 a single dirigible balloon, even of the size of the one now at Fort Myer, Virginia, which cost less than $10,000, the American army and navy would not have long remained in doubt of the presence of Cervera's fleet in Santiago Harbor.

The world is undoubtedly growing more humane year by year. We have arrived at a conception of the principle of an efficient army and navy, not to provoke war but to preserve peace, and it is believed that, following this principle, the perfection of ships of the air for military purposes will materially contribute, on the whole, to make war less likely in the future than in the past.

* Abstracted from a paper read before the American Association of Mechanical Engineers.

In recent years the expensive and dangerous practice of taking down worn-out and superfluous factory chimneys piecemeal has been replaced by the safer and more expeditious method of felling them, as trees are felled, if an open space of sufficient extent is at hand. The chimney is cut half way through at the base and prevented from falling by wooden wedges driven into the incision. Straw saturated with petroleum is placed in contact with these wedges and ignited. The heat of the fire dries the wedges and causes them to contract and allow the chimney to fall toward the side of the incision, without endangering buildings on the opposite side. A chimney 130 feet high, near Privas, France, was recently felled in this way, without causing any damage to buildings standing very near it. Usually the falling chimney breaks during its descent, but this chimney, in which the bricks were imbedded in a very strong cement, fell in one piece and did not break until it struck the ground.

A CONCRETE COAL MINE SHAFT.

A NEW WAY OF REACHING INACCESSIBLE VEINS.

BY DAY ALLEN WILLEY.

An engineering project of unusual interest is being carried out in the coal-mining regions of Pennsylvania, where the use of concrete and steel has been demonstrated to be of much importance in the formation of a shaft from the surface to coal veins.

Among the mines in the vicinity of the city of Wilkes-Barre is the Woodward. In the operation of the mine a deposit of coal has been located below such a formation that it was considered impossible to reach it by constructing a shaft according to the ordinary method. Situated in a stratum of rock below the level of the Susquehanna River, which flows through this section of Pennsylvania, the water from the river seeps into the formation above the coal. The surface is so near the level of the river, that it is frequently submerged when the water is at flood height, and the land in the vicinity is marshy.

The conditions are such that an ordinary shaft supported by timbering could not be constructed because the formation is more or less affected by water to a depth of fully 80 feet below surface where rock occurs. The problem which has confronted the engineers is how to reach the coal by the employment of some other plan of shafting. Mr. A. C. La Monte, chief engineer of the coal mine, decided upon a shaft with concrete walls to be reinforced with steel. A novel feature of this design is that the shaft literally sinks itself by reason of the manner in which it is constructed and the shoe or base upon which it rests. The first operation was the construction of a steel cutting shoe of oblong shape, 59 feet and 6 inches by 28 feet. This shoe consists of a sheet of ½-inch steel, 30 inches high, to which is bracketed about 8 inches from the bottom a 24-inch steel shelf, forming the foundation for the shaft walls. The shoe was placed at the bottom of an excavation 15 feet deep, the resting place of the shoe being accurately leveled. Forms were then erected on the shelf and concrete poured in, in the manner followed in the pouring of any concrete wall. Steel reinforcing rods were placed at regular intervals in both directions. The shoe was thus forced through the soft earth by the weight of the wall; and as the shaft sank the wall was built up, the forms being removed as soon as the concrete set, and replaced above to be repoured. The shaft kept sinking of its own weight as its height increased, the walls always being kept a little above the ground level.

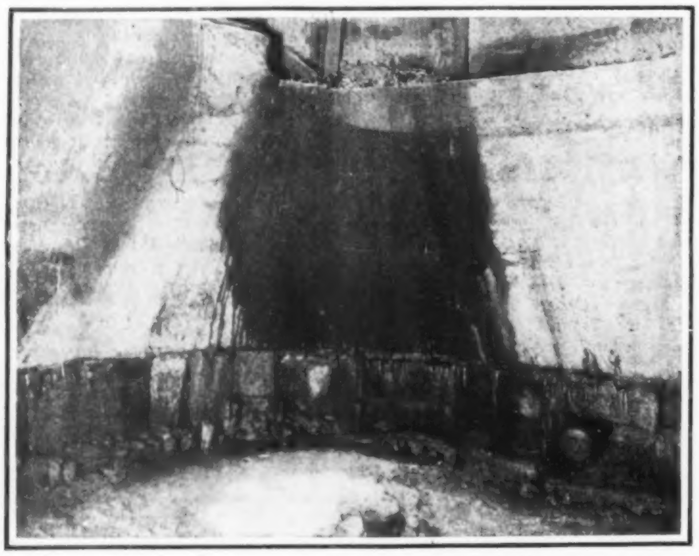
The greatest problem encountered was in keeping the shoe absolutely level, so that one side of the shaft would not sink faster than the other. The rock bed was reached about 80 feet below the ground, and as this stratum was not level, the walls of the shaft had to be propped on one side, and a concrete joint formed between the bottom and the bed of rock. This joint was made absolutely waterproof. Then the engineers began blasting through the rock, and have reached a point over 100 feet below ground. A concrete lining has been placed in the rock portion of the shaft, making it of uniform diameter and giving it a smooth operating interior surface.

The dimensions of the shaft make it no small project, even if put down through an easier formation to pierce. After piercing the rock stratum referred to, about 700 feet more must be excavated before operations on the coal veins begin. This portion of the shaft will be completed in the ordinary manner, and it is believed that the superstructure of steel and concrete will prevent any drainage or leakage of surface water below the rock on which it rests. Precaution has also been taken to prevent the shaft from being flooded when the river is high by extending the concrete wall to a height of fully 20 feet above the surface.

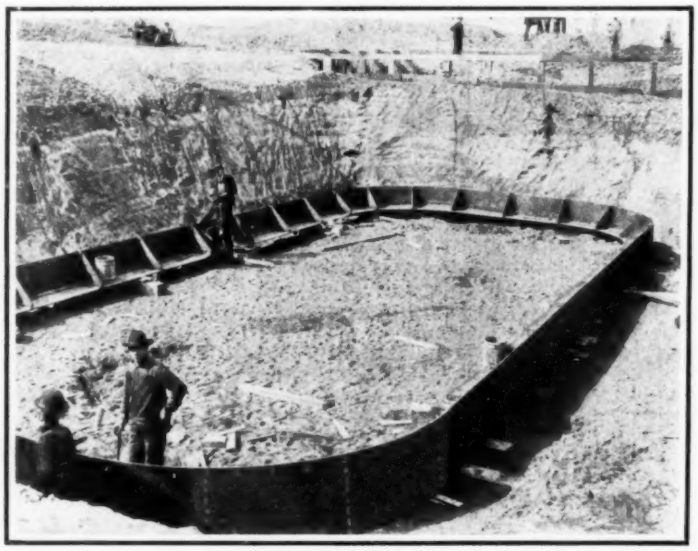
In carrying out this novel mining work, over 3,000 cubic yards of concrete were utilized in addition to the steel, the quantity of metal required being about 145 tons. The upper section of the shaft might be called a huge caisson, since so much of it is set in a water-soaked formation.

As the photographs show, the shoe is constructed of heavy steel with numerous braces, while the concrete walls of the shaft are 2 to 7 feet in thickness, and the interior is divided by a thick bulkhead of the same material. It will be noted that the steel reinforcing rods used in the work are of spiral design, giving the metal a much greater adhesive strength.

This work presents an interesting example of what can be done to reach coal and other mineral deposits in formations which are water-soaked or may be composed of loose sand. By employing this method, undoubtedly many valuable veins of coal and ore which are at present inaccessible can be reached by the miner.



INTERIOR AT BOTTOM OF SHAFT, SHOWING CUTTING SHOE AND PART OF ROCK BED ON WHICH IT RESTS.



COMPLETING THE STEEL CUTTING SHOE FOR WORKING THROUGH THE SOFT FORMATION.

A CONCRETE COAL MINE SHAFT.

THEORY OF ELECTRONS.

By Sir Oliver Lodge.

The whole idea of being possibly able to express matter in terms of electricity is one that needs reiterated explanation and emphasis. The mode in which the electrons themselves have been weighed and counted, I will not here again enter into. It may be taken as known; and if not, it can be found described in many places—among others in my book called "Electrons." But the fundamental fact on which is based the notion that matter may be an electric phenomenon, is deserving of more expanded and repeated notice; and part of this lecture must be devoted to that. For to the superficial eye nothing could be more distinct than matter on the one hand and electricity on the other. Anyone would suppose that an electric charge, whatever it is, must be a mere appanage or decoration of matter, and that by no conceivable ingenuity could it be thought of as constituting the substance of matter itself. Benjamin Franklin—whose ideas concerning electricity have in many respects become so singularly justified—would, I conjecture, have been profoundly interested, but somewhat astonished and probably skeptical, if such an idea could in his day have been authoritatively mooted. If so, it would be one of the many instances when ultra and exaggerated skepticism concerning truth and reality fails to be justified by events. Unless indeed even the present tendency be discounted, and skeptics prefer to wait till future times for a more thorough justification of these theories before even tentatively accepting them—a legitimate though not a prolific or fertile attitude.

The attribution of the material property of "mass" or inertia to elasticity entirely depends upon the magnetic properties of an electric charge in motion. *The magnetic properties of an electric charge in motion.* In that sentence I have mentioned the three fundamental attributes, or manifestations, or phenomena, of the material universe: Electric charge, magnetic field, and mechanical motion; or electric force, magnetic force, and mechanical force. These three vectors are essentially perpendicular to each other, and correspond to the three dimensions of space. They also correspond to the three chief known properties of the ether of space, which is the substratum or material basis of all activity. We do not yet know the constitution of this continuous and omnipresent medium, but it is certainly so constituted that each of these three vectors is physically possible at any point in space; and moreover it is so constituted that wherever two of them exist, the third springs into being—at right angles to both.

A charge in motion constitutes a current—"current" is our shorthand expression for charge in locomotion—and a current is always and essentially surrounded by a magnetic field. A magnet in motion generates a current in conductors, and an electromotive force in insulators. A varying magnetic field does the same, for its lines are then in lateral motion. A magnetic pole in the neighborhood of an electric charge, even when stationary, sets up a theoretical spin in the ether, round the line joining them—a hypothetical spin which can display itself by its gyrostatic action.

The result is that when a charge is in motion, the magnetic field due to the motion, when once generated, tends to preserve and prolong that motion, so that mechanical force is needed to obstruct or stop the moving charge. Similarly to accelerate or set in motion any electric charge involves the generation of a magnetic field, and therefore requires the application of mechanical force and the expenditure of energy. No such force is necessary so long as the motion is steady, no more than if the motion was zero; but directly the motion changes, whether in the way of increase or of decrease, force is immediately exerted; nor can there be any kind of change produced in the motion, either in magnitude or direction, save by the exertion of force. In other words, an electric charge in motion, not acted on by any force, will continue to move in a straight line with a uniform velocity. And if a force acts upon it, the acceleration produced is exactly proportional to the force.

Thus the reaction between electric and magnetic fields precisely simulates all the effects of mechanical or Newtonian inertia. It is an acceleration-coefficient, not a velocity-coefficient; it is not of the nature of re-

sistance or viscosity, but it is of the nature of mass. But when I say simulates—I would rather say that it accounts for, or rationalizes, or carries one step further on, the otherwise blank and bald idea of Newtonian inertia.

The first two of Newton's laws of motion are thus obeyed by electricity. Is the third law obeyed likewise? I say yes; but the answer is not so simple and easy. The peculiar condition of an advancing wave-front has to be taken into account, and we have to admit that an ethereal wave advancing with the speed of light may possess attributes which hitherto have been thought to belong only to matter, and may—indeed must—sustain the reaction of a stress whose other end acts upon the source. So that light or radiation of any kind must exert a pressure and must be the seat of a stress—a fact which, predicted by Maxwell, has now indeed been directly and experimentally observed.

If somehow there should be acceleration without the action of any material body, then waves are generated in the ether; and the mechanical force essential to the action is supplied by the reaction of the train of ether waves. It is a singular but very important case; the wave-front seems to represent adequately some of the properties of matter, and the generation of such a wave-front is the inevitable consequence of either accelerated or retarded or curved motion of an electric charge. This and this alone is the source of ethereal radiation.

To pursue this subject would lead us into the intricacies of spectrum analysis, which has already begun to throw light upon atomic constitution, but what little I propose to say on that subject will come better later.

Leaving this as a digression, and returning to electric inertia, it may be truly said that an electric charge has the property which we know as mass or inertia; and it becomes a possibility that no other mass or inertia need or does exist. This is the chief basis of the electric theory of the nature of matter. It is one of the foundations on which the notion that an atom of matter is built of electric charges must fundamentally rest.

But, admittedly, the extra mass of any ordinary charged body, due to the charge, is excessively and absurdly small. The mass depends not only on the charge but also on its concentration; in other words, on the charge and its potential. It is in fact proportional to the electrostatic energy of the charge. The mass or inertia of an electric charge is such that, if moving with the velocity of light, its kinetic energy would equal the electrostatic energy of the charge at rest. In other words, considering the charge uniformly distributed through a sphere of radius, a, $\frac{1}{2}mv^2 = \frac{1}{3}e\frac{e}{ka}$; but it is known that $v^2 = \frac{1}{\mu k}$, so $m = \frac{2}{3}\frac{\mu e^2}{a}$, a simple formula which is the sheet-anchor of the electrical theory of matter.

To build up an atom out of a reasonable number of electrons, therefore, the charge of each electron must be excessively concentrated, that is to say, must occupy exceedingly small bulk, so that an electron's intrinsic potential may be high—comparable indeed to a million volts; an astonishing value, which reduces itself to only a few volts at any distance comparable with molecular dimensions. It is indeed possible to specify the bulk of an electron which will enable us to say that its mass is wholly of the electrical kind. Every experiment made—both direct and indirect—goes to confirm the extraordinary smallness and consequent penetrating power of electrons.

At one time, not so long ago, we were in doubt about the size of atoms; some few may perhaps have been in doubt as to whether such a phrase had a legitimate meaning. I hope that this unnecessary skepticism is now set at rest, and that everybody admits the estimate of size or molecular magnitude which we owe to the genius of Lord Kelvin, among others. The extreme minuteness of the atom can be brought home to the imagination in many ways; but one striking way is to point out that in spite of the extreme rarity or dilution of the gold chloride dissolved in sea water—estimated at 1/50 grain per ton, or say one part in a thousand million, so that it appears not to be possible to extract it economically—yet that in every cubic millimeter drop of that liquid, the number of gold atoms amounts to several hundred millions: And the number of atoms of radium in any 50 cubic centimeters, or say a half pint of sea water* or of ordinary rock is about the same.

Yet in spite of their excessive minuteness we know of one definite structure which can only be about ten or a dozen molecules thick—namely the soap bubble on the point of bursting, in the region which shows itself to the eye as a black or non-reflecting spot.

Waves of light are excessively small things, of which a hundred thousand only span an inch, and yet waves of light are coarse, unwieldy things compared with atoms; so that the fineness of microscopic vision must break down in the attempt actually to see the atoms, although by more or less indirect means there is some hope that the larger kind of molecular aggregates may some day become in a manner visible, by the diffraction and other effects which they cause in a beam of light. Moreover, the excessively thin ether pulse known as an X-ray appears to be distinctly thinner than molecular dimensions, since it is able to pass through a mass of material with only a moderate amount of loss.

But although the atom is so minute, it is huge compared with an electron; and if it be true, in any sense, that an atom is mainly composed of electrons, they must be as far apart from each other inside the atom, in proportion to their size, as the planets of the solar system are in proportion to their size.

The porosity of matter so constituted is extreme, and the ultimate specks of which even an atom is composed are as it were few and far between. Though an atom may perhaps contain thousands altogether, it consists mainly of intervening space in which there is nothing but continuous unmodified ether.

That is the kind of picture which we are beginning to form in our minds, not dogmatically but as a guide to investigation; it forms a mental image of which we can trace some of the consequences, so as to be able to check and amend it by observation and experiment.

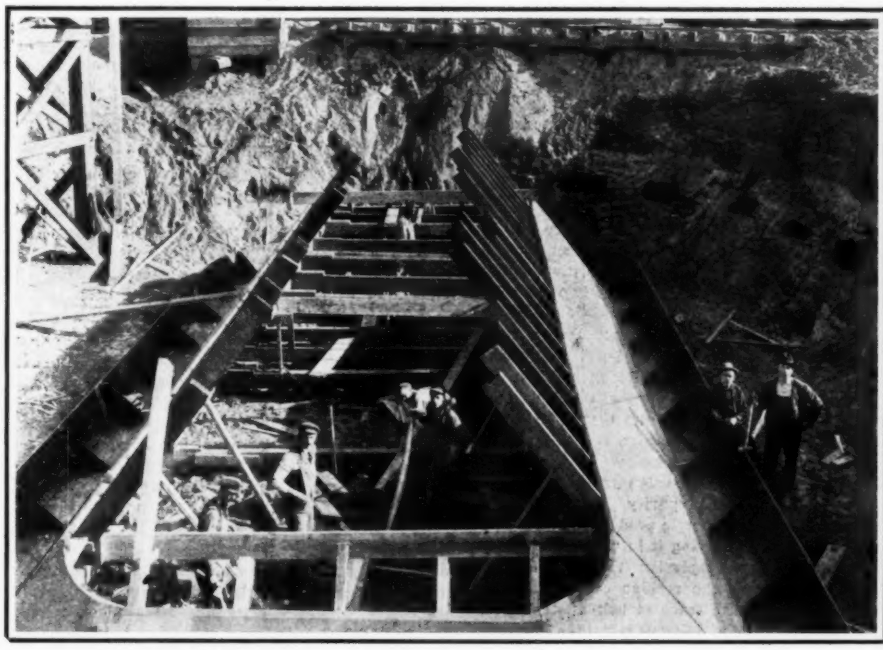
* Joly estimates the proportion of radium in sea water as 2×10^{-14}, Phil. Mag., March, 1908.

It is on this basis that I have been led to attribute so excessive a density or massiveness to the ether—that is to say, on the supposition that it is of ether that the electrons are really composed, that they are, as it were, "singularities" or some kind of structure or strain or motion-center in the ether, differing from it only in the circumstance of their arrangement, not in their density or concentration. A really continuous fundamental medium cannot be either rarefied or condensed; it must be uniformly everywhere. Accordingly, whatever density a discrete aggregate of scattered particles may possess, the density of the continuous medium, which composes them and fills up all the intervening spaces, must be greater, and may be immensely greater.

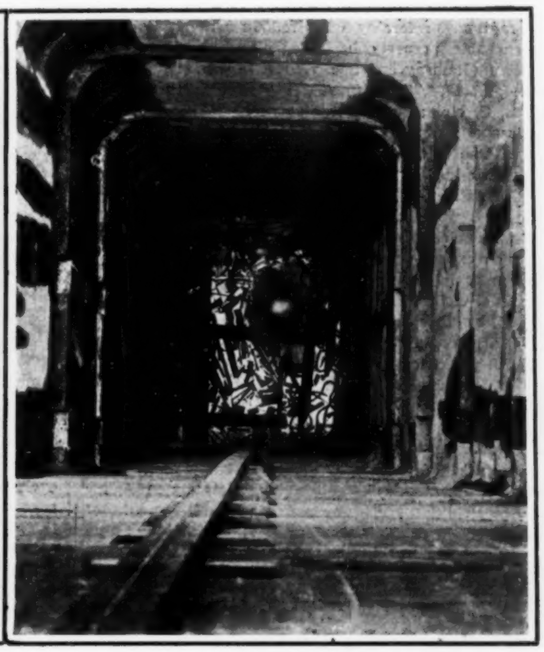
The reason why matter appeals to us so clearly and strongly is because our present bodies are composed of it, and because our sense-organs have been evolved to respond to its various motions; but matter turns out to be a mere faint misty modification of the great medium itself; and, compared with it, is like a gauzy cobweb or mist or a milky way. I repeat this because I believe it will be found to be a fact of profound significance—a significance as yet undreamed of—significance which could only at present be dealt with in terms of speculation, a thing desirable to avoid until we can adduce a more substantial foundation for it.

A movement to connect nearly all the groups of islands in the South Pacific by a system of radiotelegraphy is on foot, according to the Western Electrician. It is proposed to include in this system Australia, New Zealand, and the Fiji group as well as the New Hebrides, the Solomon, Samoan, Cook, Society, and Marquesas Islands, and the phosphate islands of Ocean, Pleasant, and Makatea. It is expected that the various governments having possessions in the South Pacific will aid in the establishment of the proposed system. Negotiations have already proceeded so far that the success of the efforts seems to be almost assured, says Mr. J. D. Dreher, the United States consul in Tahiti. As the nearest available ocean-cable office to Tahiti is at Auckland, 2,250 miles away, from which a steamship arrives at Papeete once every twenty-eight days, and a direct communication by steamship with San Francisco, 3,658 miles distant, is had once in every thirty-six days, it will be understood how deeply interested the French colony of Tahiti and its dependencies are in the complete success of these negotiations. The name of the proposed company is the Pacific Islands Radiotelegraph Company. Of the proposed capital of $340,000, the owners of the phosphate-deposits on Ocean and Pleasant Islands have subscribed about one-seventh. In this radial system there will probably be ten or twelve circles, the largest having a radius of 1,250 miles, and requiring for each station an engine of 60 horse-power. It has not yet been decided where the main office of the proposed company will be.

The best all-round rock-drill steel contains, according to the manufacturer's rating, 0.50 to 0.60 per cent carbon, for this combines maximum toughness with a hard cutting edge. Milder steel should be used for the shanks, since it is cheaper, welds up to the cruciform easier, and is less liable to crystallize and break



ATTACHING STEEL CUTTING SHOE TO BASE OF SHAFT FRAMEWORK.



VIEW OF THE INTERIOR OF SHAFT.

A CONCRETE COAL MINE SHAFT.

ACTION OF RADIUM ON DISTILLED WATER.*

THE POTENT CHEMICAL EFFECT OF A NEWLY DISCOVERED GAS.

BY SIR WILLIAM RAMSAY, K.C.B., F.R.S.

The emanation from radium is one of the most potent, if not the most potent chemical agent which exists in nature. Of all known substances it is endowed with the greatest content of potential energy: for one cubic centimeter contains, and can evolve, nearly three million times as much heat as an equal volume of a mixture of two volumes of hydrogen with one of oxygen. The spontaneous change which it undergoes, moreover, is accompanied by the emission of an immense number of corpuscles, expelled with a velocity approaching that of light in magnitude, and which have a remarkable influence on matter. For some years I have been engaged in studying its chemical action, and in this memoir I shall attempt to describe its action on pure water.

Since the discovery of this gas by Dorn in 1900, it has been the subject of many researches, physical for the most part. What we know of its properties can be told in a few words.

It is a gas of unknown, but probably considerable density (Rutherford and Miss Brooks, Trans. Roy. Soc. Canada, 1901), which unceasingly escapes from salts of radium, preferably dissolved in water. Its most remarkable property is its spontaneous change into helium (Ramsay and Soddy, Proc. Roy. Soc., 1903, 72, 204, and 1904, 73, 346) and other products (radium A, B, C, etc.); the latter also possess a limited life; it is supposed that radium F is identical with polonium. The emanation obeys Boyle's law; its spectrum was examined by Ramsay and Collie (*ibid.*, 1904, 73, 470). Attempts have been made to determine its density by measuring its rate of diffusion, and so to gain knowledge of its molecular weight; the results of such experiments are somewhat unsatisfactory, but appear to indicate a density of about 100, and a consequent molecular weight of about 200. It resists attack by all chemical agents which have been tried; like argon and its congeners, it is unaffected by sparking with oxygen in presence of caustic potash or by prolonged contact with a red-hot mixture of magnesium dust and lime; it would therefore appear to belong to the helium group of elements. If this be so, its atomic weight and its molecular weight should be identical, for its molecule is probably monatomic. Perhaps its atomic weight is approximately 216.5, for the mean difference between five pairs of elements, of which one example is tin and lead, is 88.5; and this number, added to the atomic weight of xenon, 128, gives 216.5. The number of 216.5 would correspond approximately to a density of 100.

It can be condensed by cooling it to —185 deg. by means of liquid air (Rutherford and Soddy, Phil. Mag., 1903, [vi], 5, 561). Rutherford and Soddy state that it is non-volatile at temperatures a few degrees below 150 deg.; but it must certainly possess a vapor pressure even at —185 deg., for when a complete vacuum is made over the frozen emanation, in pumping off other gases, luminous bubbles travel down the fall-tube of the Töpler pump.

It emits only α-rays; and its rate of half-decay is 3.71 days (Rutherford), 3.99 (Curie), and 3.86 (Sackur). The Curies discovered that radium continually evolves heat; and Rutherford has shown that the major part of the heat is due to the disintegration of the emanation; the emanation given off by a gramme of radium in an hour evolves about 75 calories. This heat owes its origin, not only to the disintegration of the emanation, but also to the spontaneous change of several of its products. The total heat evolved during the life of a cubic centimeter of emanation is close on 7 million gramme-calories. Now, the heat evolved on explosion of a cubic centimeter of a mixture of hydrogen and oxygen in theoretical quantity is about 3 calories; it follows that during its disintegration the emanation emits nearly 2½ million times as much heat as that of an equal volume of hydrogen and oxygen combining with explosion to form water.

It was with the design of applying this enormous store of energy that the experiments about to be chronicled were begun, about two years ago. The quantity of radium at my disposal has varied from time to time, for it was in use for other experiments.

1. The Evolution of Heat by the Radium Emanation.—Although Rutherford has made a quantitative estimation of the amount of heat evolved from the emanation, a qualitative confirmation will here be given; any confirmatory evidence has some value.

Two thermometers were constructed; one, an ordinary thermometer, the scale of which registered tenths of degrees; the bulb of the other was hollow, so that a quantity of the emanation, mixed with hydrogen, could be introduced into a chamber surrounded by the mercury of the thermometer. The two thermometers were carefully compared. They were placed, after filling the hollow bulb of one with the emanation obtained in five days from 162 milligrammes of radium bromide, in two silvered vacuum vessels, and they rested in cotton-wool, with which the vacuum vessels were lightly packed. These vessels were placed side by side in a room of which the temperature remained nearly constant. The following table gives the differences between the two temperatures; needless to say, that of the thermometer containing the emanation was the higher:

Date—November,	20.	21.	22.	23.	24.	25.	26.	27.	28.	29.	30.
Difference, deg...	0.52	0.73	0.63	0.53	0.48	0.34	0.25	0.24	0.19	0.16	0.13
Date—December,.	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	
Difference, deg...	0.13	0.13	0.12	0.10	0.0	—0.01	—0.03	±0.03	—0.01	±0.02	

These figures show incontestably that the emanation evolves heat during its change, and that the amount liberated decreases from day to day.

2. The Relative Amounts of Oxygen and Hydrogen Evolved, along with Emanation, by the Action of Radium Bromide on Water.—Giesel (Ber., 1902, 35, 360; also 1903, 36, 347) was the first to observe this decomposition; Bodländer found the gaseous mixture to contain 12 per cent of oxygen and 88 per cent of hydrogen; the excess of hydrogen was 64 per cent. Later, Ramsay and Soddy (*loc. cit.*) found 29.8 per cent of oxygen and 70.2 per cent of hydrogen; the excess of hydrogen is 10.6 per cent. Whence comes this excess? They ascribe it to the oxidation of the grease of the stop-cock; but that danger was avoided in the work of which an account will be given. The following experiments were made in the hope of solving this problem.

The first question to be answered was: Does radium bromide evolve gas when dissolved? A very pure sample of bromide, bought from Büchner & Co., of Brunswick, was employed. It is worth noting that five samples of bromide, bought from that firm at different times, all had the same relative discharging power on an electroscope, as measured by the β-rays evolved, and the natural conclusion is that they all possessed the same degree of purity. The volume of the gas obtained from the sample used (which weighed 50 milligrammes), on dissolving it in water, was 0.1444 cubic centimeter; after explosion the volume was 0.0477 cubic centimeter; the residue consisted solely of hydrogen, mixed with a trace of helium, the latter detected by its spectrum. Now, crystalline bromide probably contains two molecules of water, which should be resolved into oxygen and hydrogen by the action of the radium. The excess of hydrogen is 33 per cent, and it must be supposed that the gases were occluded by the bromide and liberated on its being dissolved.

The next experiments, made at considerable intervals of time, show the yield of "electrolytic gas," with the excess of hydrogen, obtained from varying amounts of radium bromide:

	Weight of $RdBr_2, 2H_2O$ gram.	Time of collection in hours.	Volume of gas in c.c.	Volume per gram per 100 hours in c.c.	Excess of hydrogen per cent.
1.	0·0600	96½	1·67	28·0	14·50 *
2.	0·0600	168	2·88	28·6	4·44
3.	0·1090	240	8·91	34·0	3·65
4.	0·1090	196½	6·86	32·1	13·90 *
5.	0·1090	336	16·43	44·9	6·13
6.	0·0700	192	2·57	19·1	16·00 *
7.	0·1000	168	5·09	30·3	3·76
8.	0·1000	168	4·93	29·3	7·23
9.	0·1620	48	3·18	41·8	7·83
			Mean	32·0	Mean 5·51

* The quantities marked with an asterisk had remained in contact with mercury for a night before being measured. They have been omitted in taking the mean.

The inequality in these results may be accounted for by several considerations. First, the emanation is soluble in water, and it decomposes water; hence, if the gases remain in contact with the solution, more water is decomposed than if they are removed by the pump shortly after their liberation. Second, the emanation causes recombination of hydrogen and oxygen at a rate which depends on the amount present, and probably on the temperature. Third, the emanation causes oxygen to attack mercury when they are left in contact. The following special experiment illustrates this fact.

The initial volume of a mixture of emanation with pure oxygen was 2.13 cubic centimeters; after being kept for five days over mercury it had decreased to 1.97 cubic centimeter, and the surface of the mercury had become coated with a white deposit, which gradually changed to red, and appeared to consist of mercuric oxide. A similar experiment with hydrogen left the surface of the mercury undimmed.

For these experiments on the volume of "electrolytic" gas produced by the emanation, the radium bromide was dissolved in water in little bulbs, sealed to a common tube connected with a Töpler pump. To prevent possible leakage, after each removal of gas the reservoir of the pump was raised so as to cause the mercury to leak past the valve and to pass a stop-cock closing the tube connected with the bulbs; the gases were thus confined by mercury and did not come into contact with the grease of the stop-cock. The entrance tube to the pump was capillary, and so the surface of contact of gas and mercury was very small; the excess of hydrogen cannot be ascribed to the attack of the mercury. Even in experiments 1, 4, and 6, when the gases remained for a night in contact with a large surface of mercury in the collecting tube, of 1.5 centimeter diameter, the mercury was not much attacked. The arrangement prevented the attack of the grease by the oxygen in presence of emanation; before it was adopted, carbon dioxide was always detected spectroscopically, but after its adoption none was present.

To account for the excess of hydrogen, several hypotheses may be suggested. It is conceivable that hydrogen may be one of the products of disintegration of radium; but it is very improbable that it should be formed in such large amount. An experiment may be cited here which bears on the subject. A bulb containing 17 milligrammes of radium bromide was sealed to the pump. The color of the bromide was chocolate-brown, but some hours after a vacuum had been made its color changed to white, and it appeared to have dried. After standing for a day, a little gas was pumped off; it did not explode on passing a spark, but after it had been mixed with half its volume of oxygen, a spark caused explosion, and there was no visible residue. Some days later, a second bubble was extracted: when introduced into a vacuum tube, it showed the spectrum of hydrogen; a week later no gas could be pumped off.

It is well known that minerals containing thorium and uranium always contain helium (Ramsay and Travers, Proc. Roy. Soc., 1897, 62, 328); and some months after the discovery of helium an attempt was made to ascertain whether the helium existed in a state of combination with one of the constituents of the mineral. Several experiments were made in which the mineral was heated with hydrochloric or sulphuric acid, and the ratio of the hydrogen to the helium in the liberated gas was determined. The problem, however, was complicated by the fact that ores of uranium always contain that element as UO_3, which is reducible by hydrogen to UO_2; it would otherwise be possible to deduce the valency of helium. An imaginary example will make this conception clear. Suppose that ammonia were so unstable that immediately on its liberation it were to decompose into hydrogen and nitrogen. If it were required to determine the valency of nitrogen in magnesium nitride, the action of water, which actually liberates ammonia, would, under the supposed conditions, yield a mixture of one volume of nitrogen with three of hydrogen. The absorption of the hydrogen by a reducible agent would prevent the accuracy of such an experiment.

Our knowledge of the transformation of radium emanation into helium alters the problem. It is no longer likely that helium is contained in the mineral in a state of combination; it is almost certain that the gas is distributed through the mineral in a molecular condition, having been formed *in situ* owing to the disintegration of the radium in the uraninite; or possibly owing to the disintegration of the uranium itself, though we do not know whether helium is one of the products of the disintegration of uranium. Still, it must be noted that if α-rays consist of helium, they are emitted during the change of uranium into uranium X.

Returning to the question, is hydrogen one of the products of the disintegration of the emanations of radium and thorium? some help may be gained by considering thorianite, the cubical mineral from Ceylon. It contains little reducible oxide, and when heated or dissolved it yields a relatively large amount of helium. It has been found, and will be described in a subsequent paper, that thorium nitrate from thorianite probably yields helium on standing, and De-

* Read before the Chemical Society, London.

bierne has shown that helium is also one of the products of disintegration of actinium. Now thorianite, heated in the vacuum with sulphuric acid diluted with its own volume of water, gives very little, if any, hydrogen. From 1.3779 grammes of the mineral, I obtained 8.37 cubic centimeters of gas, after removal of carbon dioxide; oxygen was added, and sparks were passed for half an hour; after removal of the oxygen with phosphorus, the residue, measuring 8.05 cubic centimeters, consisted of pure helium; the volume of the hydrogen was therefore 0.32 cubic centimeter, or 0.23 cubic centimeter per gramme; the atomic proportion would be one atom of hydrogen to thirteen of helium.

In a second experiment, where the thorianite was fused with sodium hydrogen sulphate, a mixture of sulphur dioxide, oxygen, and helium was obtained. Part of the sulphur dioxide owes its origin to the decomposition of sulphuric anhydride; by estimating the oxygen, calculating it to sulphur dioxide, and subtracting that quantity from the total sulphur dioxide, the remainder, 16.34 cubic centimeters, was evidently produced by the oxidizing action of sulphuric acid on the U_3O_8, which was transformed into $3UO_2$, and on the $2FeO$, converted into Fe_2O_3; this would have required 16.30 cubic centimeters of sulphuric dioxide. It may be stated, therefore, that hydrogen is probably not one of the products of the disintegration of thorium, and, from analogy, a similar conclusion may be drawn as regards radium bromide.

The hydrogen pumped off from the solid radium bromide is in all probability derived from the water of crystallization of the salt. But the question still remains unanswered—whence arises the excess of hydrogen? What becomes of the oxygen?

A second possibility is that the radium bromide is decomposed into metallic radium (which would attack the water and yield hydrogen) and into bromine (this suggestion has been made, indeed, by Giesel); and bromine is easy to identify. Or, again, it may be suggested that ozone is a product of the action of radium on water, and consequently the initial volume would be too small. But ozone, like oxygen, explodes quantitatively with hydrogen, so that its presence would not account for the excess of hydrogen.

To test these suppositions, the following experiment was made. A bulb containing 70 milligrammes of radium bromide, dissolved in water, was sealed to a small U-tube containing a faintly acid solution of potassium iodide and starch. During seven days, bubbles of gas passed through this solution, but no blue color was seen, even on heating the bulb, so as to expel any trace of bromine which might have been liberated. This would also exclude ozone. It has been remarked that the odor of ozone may be perceived on opening a capsule containing radium bromide; I have opened many capsules, and I have never noticed this. Moreover, an experiment which has been in progress for more than two years negatives the supposition. The gases from 212 milligrammes of radium bromide have been removed every two or three days by means of a Töpler pump. The mercury shows no trace of ozonide; it is absolutely untarnished, and has shown no tendency to wet the walls of the pump. A single bubble of ozonized oxygen would, as is well known, cause the mercury to adhere to the glass, and render the pump useless until cleaned. It may therefore be taken as certain that ozone is not produced by the action of radium bromide on water, in absence of organic matter. I have no experiments to show whether the presence of organic matter might not lead to its formation.

Yet another two suggestions may be made. They are that the radium bromide may be oxidized to bromate, or that hydrogen dioxide may be formed. To test this, I added a drop of a mixture of iodide of potassium and starch, slightly acidified, to an old solution of radium bromide; no coloration was visible. These hypotheses must also be rejected.

3. The Action of Radium Emanation on Water.—As already mentioned, the amount of energy evolved during the spontaneous transformation of radium emanation is enormous. Supposing the density of the emanation to be 108, 1 milligramme liberates no less than 720,000 gramme-calories in thirty days. Supposing, too, that all this energy were expended in decomposing water, it should be sufficient to resolve nearly 200 grammes of water into oxygen and hydrogen.

Looking at the question somewhat differently, one cubic millimeter of emanation should liberate about 2.3 liters of explosive gas, if all energy were to be expended in that manner. But although the emanation does decompose water, the amount of water decomposed is far from the quantity mentioned.

The experiments were carried out in the following manner. The bulb *A* (Fig. 1) contained three or four cubic centimeters of pure distilled water. The inverted siphon, *B*, dipping under mercury in the reservoir, was sealed at *C* in such a way that the least pressure broke off its capillary point. The water was then frozen with liquid air, and a vacuum was made through *D*, which was sealed to a Töpler pump. The stop-cocks were then closed, and the emanation drawn from the dissolved radium bromide, and mixed with oxygen and hydrogen, contained in the small gas-tube, *E*, was introduced after explosion into the bulb by pressing the tube down on the point *C*. The gas entered the capillary tube up to the closed stop-cock, *F*. This stop-cock was then cautiously opened, and all gas entered the cooled bulb, care being taken not to introduce any mercury. After some minutes, all emanation had condensed, and the stop-cock, *g*, was opened, and the excess gas, consisting chiefly of hydrogen, was pumped off. Operating in this manner, the bulb contained only water and emanation. The gas removed before sealing the capillaries at *H* was analyzed.

To insure complete contact between water and emanation, the bulb was attached to the crank of a small hot-air engine, and shaken continuously for a month.

The results of three experiments are given in the following table:

	Initial volume of gas from radium bromide in c.c.	Excess of hydrogen in c.c.	Per cent.	Volume of gas produced by the action of the emanation of water.	Excess of hydrogen.	Per cent.
1.	9·036 *	0·339	3·76	1·810	0·053	2·93
2.	4·765	0·138	2·90	3·561	0·137	3·85
3.	15·590	0·316	2·02	4·013	0·582	14·50

* The volume of the emanation added was of the order of 0·03 cubic millimetres.

I cannot explain the third result; there was no oxidizable matter in the bulb, and the experiment was well carried out.

It is evident that the emanation alone can decompose water, and that it yields excess of hydrogen. The cause of this excess cannot be any one of the possible ones already considered, except the formation of hydrogen peroxide, but even that is excluded by this experiment: the bulb containing the water, after gas had been pumped off, was left in connection with a tube filled with phosphoric anhydride until all the water had evaporated and had been absorbed by

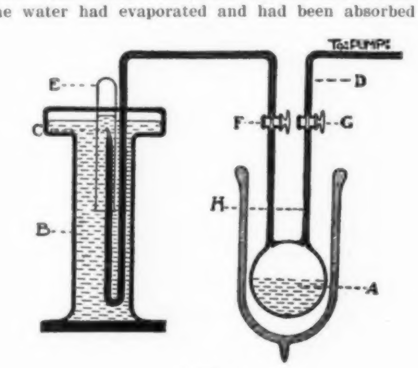


FIG. 1.

the anhydride. A minute bubble of gas was collected; on explosion, it gave absolutely no residue. Had the water contained peroxide, this bubble should have consisted of oxygen. In the other two experiments the water was tested by means of iodide of potassium and starch; there was no liberation of iodine.*

4. The Action of the Radium Emanation on a Mixture of Oxygen and Hydrogen.—An experiment was next made to ascertain whether the presence of the emanation would cause combination of oxygen and hydrogen; the gas extracted from the radium bromide was suitable for this purpose. Some of this mixture was divided into two. The first portion, 3.174 cubic centimeters, was exploded; it gave 0.179 cubic centimeter of hydrogen in excess, or 5.64 per cent. The second portion was sealed into a bulb on January 29, 1905; it was opened on February 20. It consisted originally of 2.120 cubic centimeters, and its final volume was 1.483 cubic centimeter, equivalent to a recombination of 30 per cent of the original gas. On explosion, a residue of hydrogen was obtained, equal to 5 per cent of the original volume, 2.120 cubic centimeters.

A second experiment, in which 2.035 cubic centimeters of mixed gases were sealed up with the emanation on November 20, 1906, the bulb was opened on December 27, and its volume was then 1.480 cubic centimeters, equivalent to a recombination of 27.2 per cent of the original gas; it contained 5.61 per cent of excess hydrogen, reckoned on the volume 2.035.

It appears, then, that oxygen and hydrogen recombine in presence of the emanation. The gases were dry when introduced into the bulb, and they were at a reduced pressure, probably about a quarter of an atmosphere, while exposed to the emanation. It may here be mentioned that Messrs. Berger Davis and C. W. Edwards (J. Soc. Chem. Ind., 1905, 24, 266) noticed that solid radium bromide, left in contact with a mixture of oxygen and hydrogen, induces slow combination.

These experiments prove that the action of the emanation on a mixture of oxygen and hydrogen is a reversible reaction, and that the velocity of decomposition of water is greater than that of recombination of the resulting gases, for water is decomposed by emanation.

5. The Rate at which Water Is Decomposed by Emanation.—It is difficult to solve this problem, on account of disturbing factors. These are: (1) At the beginning of the experiments the emanation is wholly dissolved in the water. After some hours, gas is evolved, and the emanation divides itself between the water and the gaseous mixture, in such a manner that that part of the emanation which remains in solution decomposes the water, and it is to be presumed that the portion mixed with the gases causes them to recombine. An experiment has not been made (and it would be very difficult to carry out) to test whether steam is decomposed by the emanation. (2) It was impossible to prevent the gaseous mixture touching the stop-cock, and consequently coming into contact with grease; when this occurs, carbon monoxide and dioxide are produced. (3) It was impracticable to avoid the use of mercury, and it has been mentioned that mercury is oxidized. But below the fairly deep layer of water the mercury, it should be noted, remained untarnished. Hence the results do not show correspondence between the amount of emanation present and the quantitative action on water. Moreover, it is not improbable that some of the products of the change of the emanation have also an action in decomposing water, although nothing is known as regards this. In spite of these objections, the results are perhaps worth recording.

The initial gas was obtained from 212 milligrammes of radium bromide in three days; its volume at normal temperature and pressure was 3.935 cubic centimeters. After explosion, the excess of hydrogen was removed by addition of a sufficient quantity of oxygen; the final residue, amounting to 0.093 cubic centimeter, was introduced over several cubic centimeters of water, standing over mercury in a measuring-tube provided with a black point, to which the level of the water could be adjusted. The minute bubble was well shaken with the water, and allowed to stand from November 25, 1905, until January 8, 1906; and daily readings were taken, temperature and pressure being noted, and the pressure of water-vapor allowed for. The readings are as follows:

	0.	1.	2.	3.	4.	5.	
November ...	25.	26.	27.	28.	29.	30.	
C. c.	0.093	0.611	0.980	1.23	1.42	1.57	
	6.	7.	8.	9.	10.	11.	12.
December	1.	2.	3.	4.	5.	6.	8.
C. c.	1.66	1.74	1.79	1.84	1.88	1.94	1.98
	13.	14.	15.	16.	17.		18.
December	9.	10.	11.	12.	13.		Jan. 8.
C. c.	2.07	2.00	2.00	2.01	2.04		2.14

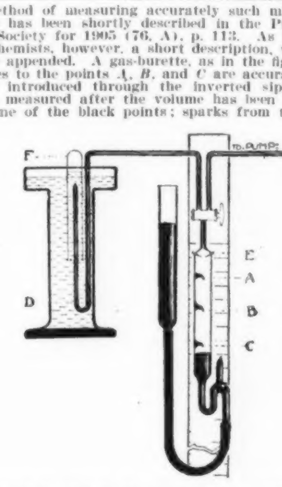
This final gas was then analyzed.

Assuming that the initial gas present was oxygen, it composition was:

Oxygen originally present....	0.093 c. c.	
Carbon dioxide	0.850 "	
Hydrogen and oxygen........	0.726 "	
Excess hydrogen	0.471 "	equivalent to 23.0 per cent
	2.140 c. c.	

It would be natural to suppose that if all emanation remained dissolved, not escaping into the gases produced, the rate of decomposition of the water would be proportional to the rate of decay of the emanation, supposing the decomposition of the emanation to be due solely to the latter; if, however, the decay of

* The method of measuring accurately such minute quantities of gas has been shortly described in the Proceedings of the Royal Society for 1905 (76, A), p. 113. As it may prove useful to chemists, however, a short description, with a drawing, is here appended. A gas-burette, as in the figure, is used. The volumes to the points *A*, *B*, and *C* are accurately known; the gas is introduced through the inverted siphon, *D*; the pressure is measured after the volume has been carefully adjusted to one of the black points; sparks from the terminals



at *E* are passed to explode the gas, and it is again measured; pure oxygen, made from permanganate, is then introduced, and it is again measured, exploded, and measured again. The gas is then expelled into the small tube, *F*, into which a little globule of phosphorus has been previously introduced and melted; the top of the tube is gently heated; the phosphorus burns and absorbs oxygen, and the residual gas, if any, is withdrawn and measured; there is usually no residue. If there is, it may be introduced into a spectrum tube and its nature determined; or if it be nitrogen, it may be removed by sparking with oxygen.

other products, radium A, radium B, and radium C, is also accompanied by the decomposition of water, the problem becomes a very complicated one.

The curve obtained by plotting the rate of increase of the gases formed against time shows a much more rapid increase than the rate of decay of the emanation would warrant. The period of half-value of the emanation is 3.8 days, that of the increase of gases is 2.53 days. The curves, however, resemble each other in character. The lives of radium A, radium B, and radium C, are very short, their combined half-period of decay being less than an hour; but as they are being continuously produced, owing to the decay of the emanation, a constant maximum is quickly produced, which falls off as the emanation decays. Attempts to allow for this disturbing influence have been made, but without success, and it appears probable that the partition of the emanation between gas and water, and the recombination of the hydrogen and oxygen in the gaseous system, render any such attempts futile in the present state of our knowledge.

DESTRUCTIVE MARINE WOOD BORERS.

VARIOUS METHODS OF PROTECTING TIMBER STRUCTURES.

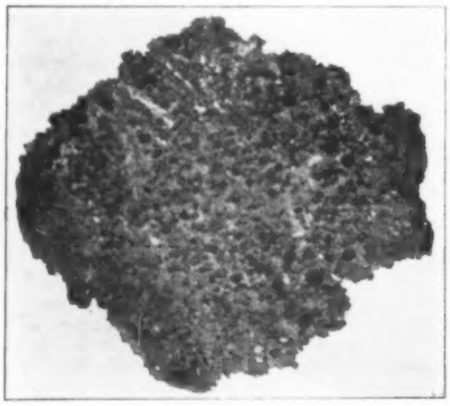
BY CHARLES. M. RIPLEY, M.E.

On both the Pacific and the Atlantic coasts, reports from railroad and other engineers indicate that the action of the teredo during the past summer has caused great destruction through docks, trestles, bridges and other structures over salt walter. The farthest point north which the teredo has yet attained according to reports has been Nova Scotia on the Atlantic coast and Alaska on the Pacific coast. Civil engineers are devoting serious thought to the matter, and particularly in the vicinity of New York this subject has demanded attention of late.

At an early stage of growth the teredo is free swimming, traveling about in the water and attacking any woodwork which may have been left exposed, entering it by a hole not larger than a pin head. After they have started their boring the teredoes grow not only in length but also in diameter, and sometimes have been known to have reached diameters as great as three-fourths of an inch. The teredo is whitish in color, and has two small flexible tubes or siphons continuously extending into the water from the small entrance hole in the wood. It is very important that these vital organs be constantly submerged in comparatively pure salt water, as it is through these organs and from the water that the teredo gets his nourishment. Thus it is that any substance which will permanently cut off the surface of the wood from contact with pure salt water, will not only kill the teredoes that are already in a pile but will prevent the entrance of other teredoes.

It is extremely difficult to inspect a pile and discover the presence of the teredo until a vast amount of damage has been done, for the reason that although the interior may be perfectly honeycombed, the exterior presents an almost perfect appearance. The writer took occasion to weigh a 3-foot section of a 12-inch pile which had been withdrawn from a bridge in a bay within a radius of 50 miles of New York city, and was astonished to find that the weight of the section mentioned was but 11 per cent of its original weight as yellow pine, which was calculated on a basis of 0.9 specific gravity. This fact was more astonishing since there were no openings upon the exterior of the pile save the tiny holes at which the teredo originally entered.

Railway engineers have planned and worked for years to prevent the action of teredo, limnoria, and other marine wood borers which destroy the piles of

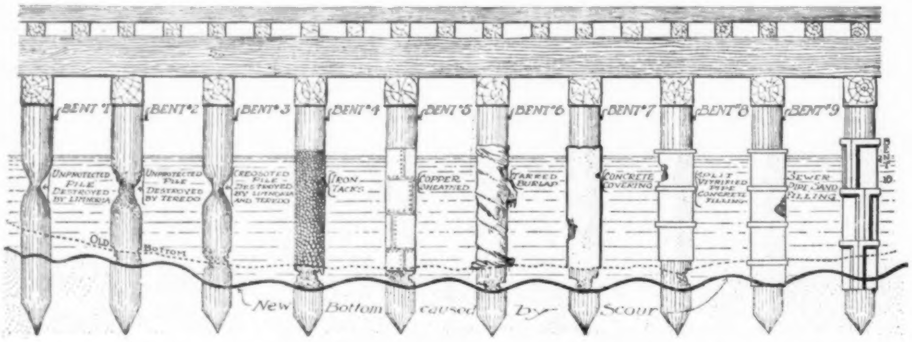


A SECTION OF A BALK RIDDLED BY TEREDOES.

docks, wharves, bridges, and trestles in the regions where salt water is to be spanned.

It was once attempted in Holland to preserve the piling of dikes by means of driving thousands of round-headed iron tacks into the pile. Small boys were employed for this purpose and more or less success attended it, but the expense is obviously prohibitory and on existing structures the work can only extend from low water upward unless the services of a diver were employed.

The copper sheathing method is a good protection. However, copper is liable to corrode in salt water, not only at the joints, but around the nail heads. The expense, both for material and for labor, in applying copper is to be considered, as is also the fact that the exact depth to which a pile is to be driven is not



THE VARIOUS METHODS OF PROTECTING WOOD PILES FROM SALT WATER WOOD-BORING MOLLUSKS.

It will be noticed that the scour of the water, which often lays piles bare below their "armor belts," is one of the principal difficulties confronting the engineer.

always known in advance, and hence the copper sheathing is likely to be made to extend either too close to the bottom of the pile, where it is useless in the mud, or too high toward the top of the pile, where it is unnecessary above the high water line. Later engineers have attempted to protect piles by means of tarred burlap wound spirally around the pile. Materials floating down stream tended to tear the burlap; also barnacles and oysters clinging to the material after the tar was more or less covered with weeds and slime tended to pull away the protection and leave the pile exposed near the top.

The lowering of the old mud line often occurs where the stream is narrowed by the introduction of piling or other obstructions. The tar burlap necessarily has difficulty penetrating the old mud line as the pile is driven, and hence as the mud line later recedes, the pile is left exposed at the bottom, a point which cannot be inspected without a diver.

Concrete has been used as a coating around piles, molds being placed by divers and the concrete poured in; one difficulty incidental to this method has been that as the mixture was poured down through the water in the mold it tended to weaken. Cases have been found where piles protected by this method were really exposed at the bottom, since nothing but gravel descended through the water to that depth and the teredo could enter the interstices between the grouting.

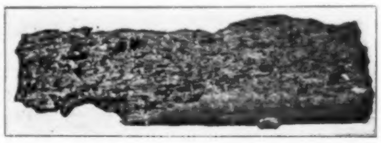
A later attempt is split vitrified pipes placed around the pile, held in place by wires, and then filled with concrete.

Another method is ordinary sewer pipe strung over the top of the pile and filled with sand. This method overcomes the difficulty mentioned in connection with a concrete covering or filling, as the sand filling allows the sewer pipe to descend as the mud line recedes, but in a new structure this method must be installed before the deck is placed. In old structures caps of the piles must be removed before the pipes can be placed. This obviously interferes with the speed of construction of new work and also interferes with traffic when applied to old structures. A serious objection is that repairs to one section or one pile necessitate the removal of the cap from that entire bent.

Many of the various sheathings used may develop a weakness in course of time; and if one vulnerable spot shows, the teredo may enter in and work destruction through the pile. All the methods mentioned—with the exception of the sewer pipe—are liable to undermining. The coverings are attached to the pile, and if the scour of the water removes the wood or earth from the base, a line of attack is offered to the teredoes.

An improvement on the sewer pipe is the new lock-joint pipe. This consists of sections of a concrete pipe, cast in halves so that it may be bolted round a pile when the latter is in position. The pipe is larger than the pile, and the space between is filled up with fine sand. Thus it is claimed that the pipe does not adhere to the pile but settles gradually and follows the mud line, always keeping the pile protected throughout the field of attacks of the marine wood borers. It may be interesting in this connection to know that the teredo must have continued access to the water in order to live. It is thus impossible for the teredo to enter a pile above this protection and live so long as this protection stands above the high water mark.

This system can be applied to old structures as easily as to new, without removing the deck, without interfering with traffic and without the necessity of employing a diver and his expensive outfit. Inspection is a simple matter since sand showing at the



ANOTHER EXAMPLE OF TEREDO DESTRUCTION.

The outer surface of the wood (at the bottom) shows no sign of the destruction inside.

WHERE THE TEREDO DOES HIS WORK.

top assures sand in place down to the lowest mud line.

Green spot soap consists of 400 parts each of cocoanut oil, kidney suet, and 40 per cent lye, 50 parts of ox-gall and 25 parts each of oil of turpentine and ultramarine blue.

THE TARRING OF ROADS.*

HOW THE WORK IS DONE.

BY PREVOST HUBBARD.

CRUDE tars, as well as specially prepared tars and tar emulsions, have been used extensively for dust prevention ever since the subject was first seriously considered, and many experiments have been conducted with these materials in France, England, and the United States. The results obtained have to a great extent been contradictory, even when the experiments have been carried on in the same manner and under the same conditions, and for this reason much confusion has arisen in the minds of road engineers as to the real value of tars.

FIG. 1.—APPLICATION OF TAR TO MACADAM ROAD.

Composition of Tars.—There are three kinds of tar—crude coal tar, refined coal tar, and water-gas tar—and, as these are the principal ones used as dust preventives, their approximate composition in percentage volumes as determined from fair representatives of each type is given below for the purpose of comparison. The notes to the table refer to the condition of distillates and residues when cold.

SPECIFIC GRAVITY AND COMPOSITION OF TAR PRODUCTS.

Kind of Tar.	Specific Gravity.	Ammoniacal Water.	Total Light Oils to 170° C.	Total Dead Oils, 170°-270° C.	Residue, by Difference.
		Per Cent.	Per Cent.	Per Cent.	Per Cent.
Water-gas tar	1.041	2.4	a21.6	b52.0	c24.0
Crude coal tar	1.210	2.0	d17.2	e26.0	f54.8
Refined coal tar	1.177	0.0	b12.8	g47.6	f39.6

a Distillate mostly liquid.
b Distillate all liquid.
c Pitch very brittle.
d Mostly solid.
e Distillate one-half solid.
f Pitch hard and brittle.
g Distillate one-third solid.

In many gas plants it is the custom to manufacture both coal gas and carbureted water gas. When this is done, the coal gas is produced at a higher temperature in order to obtain the maximum amount, and the carbureted water gas is used to raise its illuminating value. The tar thus produced is a mixture of coal and water-gas tars and will usually be of an inferior quality.

THE APPLICATION OF TARS.

There are two general methods by which tar can be used upon roads, one by applying it to the surface of the road and the other by constructing the road of tar-covered material. The application of tar to the road proper may itself be considered under two heads, and for the sake of convenience will be taken up in this way: (1) its application to the finished road, and (2) its application during construction.

Application to Finished Road Surfaces.—As early as 1867 the process of spreading or painting road surfaces with tar was considered in France, but it was not until the year 1902 that work of this kind was begun in earnest. Crude coal tar was first tried, as it was easily obtained and comparatively cheap, but little attention was paid to its character and quality.

Most crude tars are too viscous to apply satisfactorily when cold, and the use of heat to render them more fluid has been generally adopted. The addition of a sufficient quantity of lighter oils will serve the same purpose, but a corresponding loss in the binding quality of the material will be produced by this dilution.

Experience has shown that in order to get the best results from applications of tar the road should be free from dust, perfectly dry, and comparatively warm. If dust and other fine material are present the tar will not be properly absorbed by the surface and, owing to a lack of bond, will soon peel and be removed by traffic. For this reason it can be applied successfully to hard surfaces only, such as are presented by well-swept macadam roads. The presence of moisture will also prevent the tar from penetrating the road, and as a cold surface will chill and stiffen the material it is necessary that all applications be made in dry, warm weather. Before applying the tar the road should be repaired where necessary, in order to secure as smooth and even a surface as possible. If ruts and hollows are present, the tarred road will not only present a poor appearance, but accumulations of water in these depressions will produce rapid disintegration of the tar, followed by its complete removal under the action of traffic. It is desirable that repairs be made for some time previous to the tar application in order to obtain a well-bonded and consolidated surface to start with, for it has been found that fresh patches which have been tarred are not unlikely to ravel if traffic is at all heavy.

The primitive method of application which has been largely employed in this country up to the present time is as follows: The road surface is first thoroughly swept in order to remove all dust. The hot tar is then spread on and thoroughly broomed in. The road should then, if possible, be closed to traffic and the tar allowed to remain untouched for about twelve hours in order to allow it to soak in. At the end of this time, or sooner if necessary, a coat of clean sand or stone chips should be applied to absorb the excess of tar, and the surface should then be rolled several times to bring it to proper condition quickly. The preliminary sweeping of the road is sometimes done by hand, but an ordinary mechanical street sweeper is often to be preferred, as it performs the work more economically and with greater expedition. The tar is heated in an open kettle preferably mounted on wheels and fitted with a portable fire box. It is usually brought to its boiling point—about 190 deg. F.—before being spread upon the road, although a lower temperature is sometimes sufficient, and, if the kettle is of the type described above, the tar may be run out upon the road as required by means of a hose, the kettle being kept just in advance of the work. By using two kettles the process may be made continuous, one being charged and heated while the other is in use. Kettles holding easily 9 barrels, or about 450 gallons, of tar without danger of spilling over, and mounted on comparatively large wheels, are to be preferred for this purpose when long sections of road are to be treated. When it is impossible to obtain kettles mounted on wheels, a number of smaller ones holding about two barrels each are sometimes used. These kettles are moved along the side of the road as the work progresses and the hot tar is drawn off into flat-nosed watering pots, hods, or ladles, and spread by hand. In either case it is necessary to have the hot tar well broomed into the surface to obtain a smooth and uniform coat. This spreading is usually done by laborers with stiff, long-handled brooms, similar to those used in street sweeping, who follow the tar spreaders and broom carefully every portion of road surface. The excess of tar is thus pushed ahead and can be used for covering fresh surfaces.

After the tar has been spread it should be allowed to remain undisturbed for at least twelve hours, as has been stated. In cases, however, where it is impossible to keep traffic away for this length of time, one of two methods may be followed. Either one-half the width of the road may be covered at one time, thus allowing the other half to be open while the first is drying, or a coat of sand or fine stone chips may be applied at once in sufficient quantity to prevent the tar from sticking to the wheels of vehicles. If the first method is followed more lasting results are to be expected, but unless considerable care is taken the finished road will present a poor appearance owing to the overlapping of the second application on the first, which produces a seam along the center of the road. More time will also be consumed, as the length of the road will have to be gone over twice. If the second method is employed, there is danger of the tar being absorbed by the loose material rather than by the road proper, and this will result in a lack of sufficient bond. If the tar is allowed to remain undisturbed for about twelve hours it will, under ordinary conditions, be fairly well absorbed by the road, and then only enough top

FIG. 2.—FINISHED TAR MACADAM. UNTREATED PORTION IN FOREGROUND.

* Abstract from Bulletin 34 of the Office of Public Roads, Department of Agriculture.

dressing need be applied to take up the surplus. Either clean coarse sand or one-half inch hard stone chips are to be preferred as a top course, as these afford a harder and better wearing surface than most other materials, such as road dust and gravel. It is customary to finish the road by rolling this fine material into the tar, but when only a light coating is applied the rolling may be unnecessary, as the action of traffic will in a short time produce the same result.

If the tar does not contain much heavy binding material and it is found necessary to patch the road during tarring, the addition of heated pitch to these patches will better tend to consolidate them and prevent them from being torn up by passing vehicles.

If the temperature of the crude tar is raised above 190 deg. F. when being heated it is very likely to foam up, boil over, and catch fire. Bad results which have been obtained from the use of crude tar are often charged to the presence of ammoniacal liquor, and it has become customary in certain localities to use only water-free tar. A good tar from which the ammoniacal water, light oils, naphthalene, etc., have been removed and the pitch diluted with a sufficient amount of the heavier tar oils to give a proper consistency should give the best and most lasting results. There are several preparations on the market which are claimed to have these qualities. They should not be taken on faith, however, but should be examined to see if they are really what they are claimed to be. The writer has examined different lots of some of these preparations and found essential and inexcusable differences to exist.

The application of tar by mechanical means may now be considered. Owing to the considerable expense involved and the time consumed in applying the tar from kettles, a number of schemes have been devised to apply it by means of various apparatuses. In France a specially constructed sprinkler has been used with some success, which can be manipulated by three men, and which, it is stated, will cover 3,000 square meters (3,588 square yards) of ordinary roadway per day. Tar is pumped into a reservoir, and, after being heated by petroleum in a manner similar to that employed in heating the boiler of a steam-motor car, is sprayed upon the road by means of compressed air contained in an adjoining reservoir under a pressure of 5 kilos per square centimeter. If the road is first thoroughly swept and all remaining dust removed by means of a vaccum cleaner, the tar is expelled with sufficient force to penetrate well into the macadam, and therefore does not require brooming. A thin top dressing of sand should afterward be applied to the tarred surface.

In England the application of tar by mechanical means has been studied by means of a trial competition of various machines carried on by a representative committee of engineers and others interested in road matters. Some exceedingly ingenious devices were produced at this contest, which give promise of good results. A number were designed to carry on the whole operation of tarring at one passage of the vehicle. Some are propelled by steam and so arranged that the road is first swept to remove the dust, which is drawn up by vacuum into a receptacle connected with the machine. The tar is heated and sprayed upon the road under considerable pressure, thoroughly broomed in, and the dust, previously removed, is distributed over the tarred surface. A full description of these machines has already appeared in print.*

Some attempts have been made in France to apply the crude tar cold and afterward set fire to it. By this means it is claimed that the road surface is caused to absorb the tar to a considerable extent; and as the lighter oils will be consumed and the water and ammoniacal salts driven off, all of the advantages of applying a refined tar will be obtained. It is extremely doubtful, however, if this method will ever be extensively employed, as it seems entirely probable that some of the valuable binding materials will be burned and that the remainder will become brittle and useless on account of absence of oils which give the heavier products life. If the material is to be applied cold, it is far better to dilute it with the necessary amount of suitable oils, which, while lowering the percentage of true binding base, will nevertheless act as a dust layer until they are saturated or lost by evaporation.

Use of Tar in Road Construction.—So far we have dealt only with the methods of applying tar to a finished surface. Where a new road is under process of construction, or an old road is being resurfaced, it is often desirable to apply the tar in a somewhat different manner. In these cases the road should first be shaped and consolidated as well as possible without the addition of water. The voids should be well filled with clean, fine stone chips free from dust, but an excessive amount of rolling should be avoided in obtaining this condition. If the roller is used too freely the larger stones will become rounded and covered with dust, which prevents the tar from adhering properly. Hot tar may be applied to all of the courses if desired, but sometimes only the upper course is so treated. After the tar has been applied a dressing of fine material is spread on in the manner described in the other methods of application and the whole road is well rolled. A road so treated will have all of its interstices filled with hard material and only sufficient tar to surround each individual particle. Thus all wear will be sustained by the stone aggregate and the tar will act solely as a binder. It will be seen that a road so constructed will approach very closely the road built of material which has been previously tarred.

If the tar is applied by hand, a great deal more will be taken up by the road than is absolutely required. As this means an unnecessary expense, attempts have been made to devise a method which will produce good results with a minimum amount of tar. A tar spreader similar to those already described has been tried with some success for this purpose in England and in Scotland. A brief description of this apparatus and the method of using it may serve to illustrate the most important points relative to a treatment of this kind. The spraying apparatus is mounted on wheels and is so arranged that the tar is forced from the tank in which it is heated into an air receiver under a pressure of from 150 to 350 pounds per square inch. The necessary power for pumping the air and the liquid into the receiver is obtained by means of a chain drive from the road wheel of the vehicle. From the receiver the tar is distributed upon the road by means of specially designed spraying nozzles.

In considering the relative value of these different methods of application and the character of the material which will give the most satisfactory and economical results, it is necessary to take into account many factors which have a most important bearing on the subject. There is probably no one practical and economical method which can be used under all conditions, but there are certain facts which have been demonstrated that will serve as a guide in ascertaining the proper method to follow under given conditions. Many of the results obtained, as has been pointed out, have been undoubtedly influenced by causes which were not given sufficient consideration, but the general characteristics of roads treated with tar in different ways have been ascertained and should be understood.

A properly tarred road after being subjected to traffic for a short time closely resembles asphalt. It is smooth and firm, of a more resilient character than asphalt, and is practically noiseless. While in good condition it is to a great extent waterproof and almost dustless; and, if the proper amount of tar has been applied, the resistance to traction is less than that of untreated macadam road. If too much tar has been applied, the road is apt to become soft and sticky in warm weather, thus causing a notable increase in the draft of vehicles, and it is also apt to rut badly. A few days after application almost all objectionable odor will disappear. Decayed vegetation, prolonged rains, and frost are the worst enemies of the tarred road.

The tar retains its hygienic and germicidal properties for some time. To determine this point, an investigation of the relative number of living germs existing in the atmosphere just above a tarred and an untarred road in the same neighborhood was made in France by Christiani and Michelis. They found less than one-half the number in the former case as in the latter, both in damp and dry weather.

Amount and Cost of Materials.—The amount of tar required to treat a road will depend upon the fluidity of the material when applied and the absorbing power of the road. Soft rocks, such as limestone and dolomite, will take up more tar than granite or trap and will in general give better results owing to the greater penetration of the tar and stronger bond formed in consequence. According to conditions and methods of application, a surface-treated road will require from 0.35 to 0.70 gallon of tar per square yard when application is made by hand. When applied by machine as small an amount as 0.21 gallon has been used with good results for a first treatment. With either method the application of tar must be repeated from time to time, though less is required at each successive application. If the tar is applied as the road is built as much as 1.5 gallons per square yard is often consumed if application is made by hand. By means of devices like the pneumatic tar sprayers, however, it is claimed that the road stones to the depth of 3½ inches may be well covered by the application of about 0.6 gallon per square yard.

Crude coal tar varies in price according to locality, but it can ordinarily be purchased from gas or coke companies at from 3 to 5 cents per gallon. The price of the refined tars runs from 6 to 12 cents per gallon and even higher. On account of this difference in price the use of a good crude tar is often to be preferred.

The cost of treatment for a surface-tarred road will, of course, depend upon a number of factors. In France, when done by machine, it will average about 3 cents, and when done by hand 5 cents per square yard. In this country, where it is generally applied by hand, the cost is hardly ever less than 6 cents and in a great many cases as high as 12 cents and more per square yard. This is largely due to the poor condition of our roads before treatment, which necessitates the application of more tar and more surface dressing than if they were in good condition in the first place. The cost of tarring a road during construction is very hard to estimate. In England it is claimed that the pneumatic tar sprayer will apply the tar at a cost of about $5 per mile of 18-foot roadway exclusive of the cost of the tar. It is needless to say that this figure would be greatly increased if the tar were spread by hand.

It has been stated that on account of its cheapness a crude tar is sometimes to be preferred to a refined material. In very severe climates, however, where a single application of tar is unlikely to last through the winter, it would seem advisable to apply a tar which has been diluted with dead oils or with water-gas tar in order to give it sufficient fluidity to apply cold. In this way the cost of application will be greatly reduced, and although the percentage of true binding base will be somewhat lessened, the results should under the conditions named be satisfactory. Where a road is being tarred during resurfacing or during the process of construction it is very essential that the tar contain a large proportion of binder. The use of a properly refined tar is certainly to be preferred to the crude material in this instance. While water-gas tar may be used to dilute the heavier tars, it can hardly be considered in the same class owing to its lack of true binding material. It, however, readily finds its place in competition with the lighter oils and emulsions.

Before leaving the subject of applying tar to macadam roads, those built of material which is tarred before being placed on the road should be briefly considered, at least in so far as the properties and application of the tar itself are concerned.

The tarred material may either be applied as a surface dressing to an old or new road or the whole road may be built of such material. Owing to the consistency of the tar or pitch usually employed, it is absolutely necessary that it be heated before applying, and in some cases the road stone should also be heated. It is evident that, within certain limits, the greater the proportion of pitch contained in the tar the firmer will be the bond produced. As very stiff pitch, however, exhibits a tendency to chip when cold, it is advisable to use one which contains enough of the heavier tar oils to give it life and maintain its resiliency. Attention should also be paid to the composition of the pitch with respect to its free carbon content. The same general methods are employed as those which have already been described.

On account of its hardness and porosity, blast-furnace slag is particularly suitable for work of this sort, and has been extensively used in England. The construction of asphalt macadam similar to tar macadam has also been suggested, and natural sandstone impregnated with asphalt has been employed in some localities.

In dealing with an old macadam road the application of a 3 or 4-inch course of tarred stone to the freshly cleaned surface has in some cases proved a success. If crude coal tar is used it should be thickened with a considerable quantity of pitch in order to give it the proper binding qualities, and in a case of this sort it is well to cover the old surface with a light application of hot tar, in order to secure a good bond between it and the new course.

One of the most promising roads of this type is constructed according to what is known as the Gladwell method. The old road is first covered with a matrix composed of tar and stone chips. Broken stone is then applied to the depth of 4 inches and the road well rolled. By this means the tar matrix is forced upward and binds the broken stone firmly together. A surface application of tarred chips, which should be well rolled, gives the road the proper finish.

* Surveyor, 1907, 31, Supplement, p. 67; Surveyor, 1907, 32, 461.

It has long been known that sea water contains gold in solution, but in quantities so small that all attempts to extract it have proven unremunerative. Luther Wagoner has recently revived the hopes of the gold seekers by demonstrating that the quantity of gold varies greatly in different parts of the ocean, the ratio between the extremes being 1 to 30, and that the richer specimens of sea water may repay working for gold. In the first place, Wagoner finds that both gold and silver are more abundant in sea water taken from great depths than in the shallow waters near the shore. The following table shows, approximately, the number of grammes of gold and of silver that he finds in a cubic yard of deep-sea water from various localities:

Locality.	Gold.	Silver.
East of Georges Bank	3.9	23.1
South of Georges Bank	1.6	4.4
Delaware Bay	1.7	11.9

It would be difficult and costly to bring these waters to land but possibly floating extracting establishments could be used.

Correspondence.

MANUFACTURE OF WHALE PRODUCTS.

To the Editor of the Scientific American:

After a whale has been killed it generally sinks; it is only the fat specimen that floats. By means of the line attached to the harpoon with its now extending claws it is cautiously hoisted to the surface of the water. A chain is placed around the tail of the animal, passed through a holegate near the bow of the vessel and made fast. By maintaining a certain speed, the carcass floats alongside the vessel, tail end first. By means of a perforated pipe connected with a hose from an air-pump and thrust into the belly of the animal sufficient air is pumped in to make it float.

Arrived at the whaling factory, the carcass is hauled by a chain attached to its tail upon the flensing plane, a large wooden plane between the two main buildings, the blubber boiler house, and the meat-boiling house and guano factory.

The flensers commence their work by making longitudinal cuts from the jaws along the body to the tail and the broad sheets of blubber of varying thickness pulled off by means of hooks and wires running from a winch at the upper end of the flensing plane.

These long sheets of blubber are then cut up into smaller pieces and fed into a chopping machine, a circular iron disk with two knives, making about 300 revolutions a minute. In this chopper the blubber is cut up into leaves of about ¾ inch thickness and taken by an elevator to the top of the blubber boiling house and by means of chutes directed to the different rendering kettles. These are sheet iron tanks generally 12 feet high and 7 feet in diameter, open at the top and with a chute at the bottom and which can be closed water tight. A steam pipe 1½ inches in diameter is run from the main steam pipe down to the bottom of the kettles and connected with a perforated pipe bent either to a circle slightly less in diameter than that of the kettle or into several parallel pipes.

As soon as the kettle is filled to about four feet from the top with the chopped blubber, steam of about 40 pounds pressure is turned on for about eight hours, after which time the contents are allowed to settle. The time for settling, which generally takes about eight hours, seems to be dependent on the specific gravity of the glue water, so it takes some experience to boil properly. After settling, the clear oil is run into a large storage tank and if rendered from blubber from the back of the animal is of a slightly yellow color and branded as No. 1 oil.

The kettle stile contains a considerable quantity of undissolved blubber and after a certain quantity of glue water is run off through the chute at the bottom, steam is again turned on for about four hours, after which time it is allowed to settle, which will take from four to six hours. The oil is now of a more yellow color and runs into a separate storage tank and generally branded as No. 2 oil. If rendered from thick and fat blubber this second boil may sometimes pass as No. 1 oil.

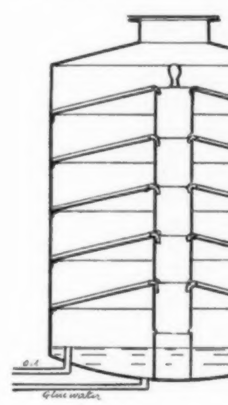
The whole contents of the kettle are now run into a large square iron tank in front of the rendering kettles. They consist of glue water and insufficiently dissolved blubber. The most of the glue water is run off into the sea and the residual undissolved blubber boiled for some hours according to circumstances and the oil after settling skimmed off and generally branded as No. 3 oil.

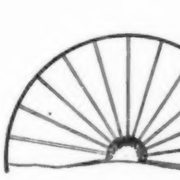
The blubber from the belly of the carcass, which blubber contains much less oil than that from the back (this will on an average contain two-thirds of oil and one-third of tissue, whereas that from the belly will contain only one-fourth of oil and three-fourths of tissue), the large and fat tongue and also fat from the intestines are likewise chopped up in the chopping machine and brought into another kettle and boiled in the same way as the other blubber, but the first boil usually gives only a No. 2 oil and the second and third boil a No. 3 or a No. 3 and 4 oil, according to the condition of the animal. The residuum from the third boil is generally run into a special iron vat and boiled with indirect steam through a coil of pipe at the bottom for upward of twelve hours, and the oil, which now is of a rather brownish color, skimmed off. This oil is chiefly used by the tanners.

The current prices are at present £20 per ton for No. 1, £18 for No. 2, £15 for No. 3, and £13 for No. 4. This difference between the grades is generally maintained also by variations in price up or down. A manufacturer who produces a certain quantity of a very light oil usually gets £1 per ton more for this than the usual price for No. 1, but he has generally so many carcasses at the factory at a time that he can select the fattest parts for this grade. He operates also with nine whaling steamers, so there is generally no lack of whales at the station.

In Newfoundland they use rendering kettles of a content of about two-thirds of ours, but as they use twelve hours slow boil with ten hours settling and five to six hours boil with five hours settling for the first and second boil respectively without getting a better grade of oil, there is no benefit in that departure. The residuum from the second boil is run into a wooden vat outside the building and heated with dilute sulphuric acid. This will, of course, dissolve the animal tissue quicker than steam alone, but we on our side do not like to use acids in connection with whale oil.

Our floating factories render their blubber in steam-tight boilers of a shape and construction as in annexed sketch. They are fitted with shelves upon which the coarsely-cut blubber is distributed. The shelves are fitted with a hook at the end next to the centrum of the boiler, and these hooks are fixed to short tubes called "pots" which form a stem in the middle of the boiler. The shelves rest with their broad ends in rings around the boiler plate. At the bottom of the boiler are discharge pipes for glue water and oil. In filling these boilers a man goes down through the manhole at the top, the iron plates and pot constituting the first shelf are sent him, and having laid the first floor, blubber is thrown down and evenly distributed until sufficient height, then a new shelf is laid, and so on until the top is reached. The manhole lid is closed and steam turned on. The rendering takes a rather short time and according to the pressure of the steam; the lower the pressure, the longer time for rendering, but the oil is then lighter than when a higher pressure is used. At the end of the operation the lid of the manhole is opened and a hook and chain from a pulley fixed to the uppermost pot, the whole is lifted and the shelves fold like an umbrella and are lifted up through the manhole. Then a new filling can take place as soon as some residuum is taken out through a chute at the bottom. The oil





obtained in this way is practically all of one quality, but it is not so light in color as the usual No. 1 oil and apt to get a "burnt" smell. It is very often sun bleached in order to get a lighter color.

The rational way of separating the oil from the animal tissue in the blubber is, however, by mechanical pressure. The oil obtained in this way has a peculiar sweet flavor, is nearly white and of a superior keeping quality. In Newfoundland they have thus several years ago abandoned the old method of boiling the blubber from seals and turned to mechanical pressure. Seal blubber is also very easily treated by pressure, being of such a soft nature. Whale blubber is, on the contrary, an exceedingly tough material which takes a large mechanical power to crush, and the tissue sticks tenaciously to the pressing surfaces. Several attempts have also been made in this country to press the blubber, but they have all failed through inefficiency of the machinery which has been constructed. During some months of experimenting on a whaling station in Shetland with some machinery I had constructed, I found a certain property of the blubber and have now constructed a press which will handle the blubber from a finback whale in less than one hour. The tissue after pressing contains about 5 per cent of oil and can be dried and used as a fertilizer with about 13 per cent of ammonia, according to an analysis made here.

Meat.—As soon as the carcass is flensed it is hauled toward the meat boiling house and the meat in large lumps cut off from the bones and taken by an elevator to the second story of the meat boiler house, where two rows of boilers of the same type and construction as those used for rendering the blubber on the floating factories are placed below the floor and with their manholes projecting above the floor. The meat is stored on the shelves, dripping from blood and oil, a messy work for the man in the boiler. When stowed full the lid is covered and steam is turned on for about eight to ten hours at 40 pounds pressure. The oil and glue water are drawn off at the bottom and steam is turned off when hardly any more oil is running. The lid is then opened, the shelves hoisted up and the meat raked out on the floor below and in front of the boilers. It is then allowed to cool and conveyed to an elevator which brings it to the top of a large circular dryer generally eight or nine stories high consisting of iron shelves surrounded by brickwork and with two or three fireplaces at the bottom for the burning of coke. The combustion canals lead one into the drier at the bottom and the second and third at intervals higher up. Rotating scrapers move the material from one shelf down on the next until it is taken out at the bottom.

The construction of these dryers is unsatisfactory for this kind of material in regard to efficiency. The meat comes in in lumps and ought to be tossed during the drying so as to separate the fibers and increase the area of evaporation. The short fall from one shelf to the next is insufficient and in order to increase the capacity of the dryer the temperature is kept too high, thereby injuring the quality of the material. But when the whalers once have got used to anything, they stick to it; reflection if there might not be something better is not their business.

The dried meat is brought on an elevator into a disintegrator and from this to a rotating sieve from which it is run into bags and shipped to Norway and used as cattle food. The demand for this article is greater than the supply, being a very concentrated foodstuff, which the cattle take very readily when they get used to it, and there is no trace of oily taste in the milk when the meat is given together with hay or cut straw. Our government experimental station made extensive trials with whale meat, when first introduced, so as to be sure about this matter.

In Newfoundland they use the Rissmuller process for treating the meat. At a right angle to the flensing plane is built a sloping plane up to a bridge and upon which the flensed carcass is hauled. On both sides of this bridge are placed a number of wooden vats, 5 feet high, 12 feet long, and 6 feet broad, inside measurements, and with lead pipes at the bottom through which steam of 100 pounds pressure circulates. The vats are filled with water to about 12 inches from the bottom and 5 pounds of soda ash dissolved in each vat by boiling. Meat is then filled in and boiled for about eight hours. After two hours the oil is skimmed off and then 35 pounds of sulphuric acid in 60 pounds of water is added and boiled for from three to four hours, after which time water is added to be able to skim off the oil. During the whole operation the meat is worked with a wooden spade to separate the fibers in the lumps. After boiling the acid, water and meat are conveyed through a chute to a special receiver where the water is run off and the meat allowed to drain.

The oil which is skimmed off is run into a wooden vat under roof and which will hold 45 to 54 casks of oil of 420 pounds each. This quantity is treated with a mixture of 200 pounds sulphuric acid and 5 gallons of water and 50 pounds bichromate of potassium dissolved in 16 gallons of water, heated and stirred for about 40 minutes. The oil bleached in this way was not lighter in color than the oil which is obtained by steam pressure boiling of the meat in our boilers and with less work. Meat treated with sulphuric acid is consequently only fit for fertilizing purposes.

Their dryers were revolving cylinders about 62 feet long and 5 feet 7 inches in diameter and with sloping ribs inside. The fuel was coal and the combustion products circulated through the cylinder, which made about ten revolutions a minute. The meat was about twenty minutes in drying and the capacity was stated to be about five tons of dry fertilizer in ten hours. Of course the meat contained more moisture, when fed in, than meat treated with steam at 40 pounds pressure in our boilers. The meat was disintegrated in the dryer by means of rolling balls and at the end of the dryer was a sieve through which the dry material was sifted.

Bones.—The bones after being stripped as well as possible for the adhering meat are split by axes, sawed or wedged into smaller pieces, which are stowed into a large horizontal boiler with manholes at the top and bottom. Steam of 40 pounds pressure is then turned on and kept boiling for about eight hours. The glue water and oil are run off through pipes near the bottom.

The bones thus boiled are then cut up by means of knives fixed to a rotating iron disk and generally mixed with boiled refuse meat or intestines in the proportion of two parts by volume of refuse and one part of bones and dried to be used as a fertilizer.

In Newfoundland they boil the bones after being split in wooden vats (like those for boiling the meat) with water and the oil skimmed off. As I understood,

the bones were shipped in this state to guano factories and were not worked up in Newfoundland.

Christiania, Norway. JOHN MORCH.

ELECTRICAL NOTES.

In a paper read before the last meeting of German Naturalists and Physicians, Mr. N. Cantor draws attention to a novel effect of electric currents. When admitting the hypothesis that the passing of electricity through metallic conductors is accompanied by the translation of inert particles, an experimental demonstration of the fact should be possible at those points where the current lines undergo a sudden change in direction. This is indeed achieved by the following experimental apparatus: A glass plate, with as sharp an edge as possible, is covered with an extremely thin metal film obtained by burning-in a reflecting layer of gold, platinum, or silver. This metal film, connected with a battery of 70 volts, is traversed by a current in such a way as to deflect the current lines on the sharp edge. Parallel to the latter there is, at 7 to 15 feet distance, an insulated wire connected with a Braun voltmeter. The voltmeter, having been charged to some hundred volts, is violently discharged when the circuit through the plate is closed. While both positive and negative electricity is thus discharged, the discharge of positive electricity is found to be more rapid. When the metal film is traversed by the electric current a photographic plate exposed for 30 minutes, 7 feet from the effective edge, will give after development a strong negative, showing a sharp reproduction of the effective edge. This photograph is in keeping with the hypothesis of charged particles leaving the edge in given directions. The author is engaged in conducting experiments *in vacuo* with a view to determining the speed and direction of these particles and studying their behavior in the electro-magnetic field. It is hoped by these experiments to arrive at some clear understanding of the state of metals traversed by the electric current.

An important telegraph undertaking is in progress by the postal and telegraphic department of the French colony of Algeria. This is the laying of a wire from the Mediterranean seaboard of the possession across the Sahara Desert to Burem on the River Niger. The work has been commenced, and the first stretch of 150 miles through Algeria to Beni Abbès is open. From the latter point it will be carried to Adrar, 650 miles farther south, and it is upon this section that work is now in progress. Beni Abbès is already telegraphically connected to Taghit, but the line is exclusively reserved for the transmission of military messages. From Adrar it will be carried 860 miles farther south to Burem, its present contemplated terminus. The construction of the desert section will be especially difficult as the heart of that expanse is penetrated, owing to the scarcity of water and the necessity of transporting the whole of the material from Algeria by camels. The wires are being supported on hollow steel poles made telescopic so as to facilitate package upon camel back, being subsequently extended and locked when set in position. In order to allow plenty of head room to the camel caravans passing underneath, the wires are being carried at a height of 15 feet above the ground. The total cost of the desert section of the line will be approximately $400,000. When completed the line will be tended by camel patrols, who will carry out all necessary repairs, small military posts being established at the wells along the line of route, some of which are 120 miles apart. It is contemplated that the line shall be continued eventually to Lake Chad, Timbuctoo, and form a junction with the existing line to Rammako and Senegambia. By this means the various French northwest African colonies will be brought into direct communication with Paris.

Many systems of fac-simile telegraphy depend on the use of selenium cells. Such selenium cells possess electrical inertia. Their variations in resistance lag somewhat behind the luminous variations to which they are due. This is why the telegraphic transmission of pictures can be effected only at rather a limited speed, and why the sharpness of records is not altogether satisfactory. It is true that ingenious compensation devices have been suggested for eliminating this drawback, but even these offer an imperfect solution of the problem. A novel process has been devised in which selenium is replaced by a substance endowed with the power of emanating electrons when exposed to light radiation. Such substances are the alkalis, such as potassium, sodium, rubidium, which in a gaseous atmosphere, e. g., diluted oxygen, emit electrons as soon as they are struck by light rays. The gaseous atmosphere thus becomes a better conductor of electricity, and the current intensity in a circuit comprising this atmosphere increases in proportion. This increase in current intensity varies as the light intensity and takes place instantaneously as soon as the light is allowed to act on the resistance. This affords the undoubted advantage of allowing light radiations of different intensity to follow up one another at a far higher rate than in the case of selenium cells, thus insuring a correspondingly higher speed of transmission. An arrangement for utilizing this principle consists of a glass vessel filled with diluted hydrogen and containing two electrodes, of which the one (connected with the negative pole) consists of platinum and the other of a body capable of giving out electrons on being lighted. The resulting fluctuations in current thus allow, at the receiving station, light effects of variable intensity to be produced, by the aid of which the transmission of pictures and handwriting can be effected in rapid succession. Instead of allowing the current fluctuations, due to variations in the conductivity of the gas, to act directly, they can be used to actuate a relay, which in turn produces this effect.

ENGINEERING NOTES.

The State of New York has organized a new division of trade schools in the Education Department, and Mr. Arthur D. Dean has been made chief of this division. This new inauguration in the Education Department of the State is intended to further the organization of two classes of schools: in the first place, factory or apprenticeship schools, which will train men in factories for the various trades; and in the second place, trade schools of the ordinary type. The new schools will be a part of the regular school system, and subject to its management, but the work will not be mingled or confused with the work of the ordinary public schools. The State will make an allotment of $500 to the Board of Education for each of such schools giving instruction to not less than 25 pupils, provided the school is maintained for a minimum period of forty weeks in one school year. The State will also contribute an additional $200 for each teacher, after the first, employed in such a school for the same period. Among the rules laid down by the Department of Education is that for these schools no teacher will be approved of who is not a recognized mechanic. It is advised that the system be organized upon an economical footing, it being suggested that often an idle building, erected for a factory, or some other purpose, may be used. All correspondence regarding this new departure will be welcomed by Mr. Dean; address Division of Trade Schools, Education Department, Albany, N. Y.

The work upon the new Lötschberg tunnel in Switzerland is being very actively carried on at present. This enterprise is the most important one of the kind in Europe, and follows closely upon the finishing of the Simplon tunnel. Its length is not much below that of the Simplon, seeing that the length of the former is about 12 miles, while the new tunnel will be nearly nine miles in length. It is run through the mountains of the Bernese Oberland, and is intended to afford a direct connection from north to south, so that passengers can make the trip from Berne by way of the new tunnel and thence to the Simplon, by a much shorter route than before. By the present railroad line it is not possible to reach the Simplon except by taking a roundabout path by way of Lake Leman and the Rhone Valley, which makes the voyage considerably longer, as the railroad must pass around the Bernese Oberland mountains, in which is situated the Jungfrau, instead of running through them, as will be accomplished by the present tunnel. It will thus be seen that the use of the Lötschberg and the Simplon tunnels will give a direct route across Switzerland and to Italy for passengers coming from the north. The southern end of the Lötschberg tunnel lies in the precipitous valley of the Lonza, one of the mountain torrents which flows into the Rhone. The mouth of the tunnel lies at Goppenstein, which is at a great height in the valley, and from which can be seen the snow-covered peaks of the Bernese Oberland range. This point is a scene of great activity, as near the tunnel mouth have been erected a great number of buildings which are needed for the operations of drilling and the light and power supply. Farther down the valley is erected a veritable town which contains the quarters for the miners and other workmen, of whom there are about 1,500 in all. Unlike the Simplon, the Lötschberg tunnel has a large section so as to accommodate a double-track road. This latter will use electric locomotives for taking the trains. The works at the end of the tunnel include a large plant, in which are installed the machines for the compressed-air supply. Power is furnished over an electric line which comes from a hydraulic plant farther down the valley, and in the works there are four electric motors of 300 horse-power. Each of the motors drives an air compressor of the Ingersoll-Rand type. The compressors furnish the air for the rock drills and also for the compressed-air mine locomotives. About 8,500 feet has already been cut at the south end of the tunnel, and at present the work is being carried on at the rate of 540 feet per month. The enterprise is controlled by a large company known as the Bernese Alps Railroad Company, among the leading officials of which are Messrs. Zünker and Chagnaud. As the mouth of the tunnel lies at a high altitude, the new railroad will be brought thence along the side of the Rhone Valley by a long cutting in the mountains, reaching the Simplon tunnel at Brigue.

TRADE NOTES AND FORMULÆ.

Fixative for Pencil, Chalk, and Charcoal Drawings.—I. (According to Töllner.) 5 parts of bleached shellac are dissolved in 100 parts of absolute alcohol. II. (According to Töllner.) 7.5 parts of gum sandarac dissolved in 100 parts of absolute alcohol. III. 40 parts of white shellac, 20 parts gum sandarac, 940 parts of spirits of wine. These solutions may be applied to the drawings by means of an atomizer or poured on to their reverse side.

Fly Paper (**Non-poisonous.**)—I. 40 parts of quassia, 5 parts colocynth, 8 parts piper longum are boiled with water to 120 parts filtrate, adding 10 parts of syrup; the paper is saturated with this and to prevent souring it is dried as quickly as possible. II. Pour 5 parts of water over 1 part of quassia wood, allow it to stand, warm, for one night and then boil until the strained fluid amounts to about 2 parts. The wood is then again boiled with 2 parts of water until 1 part remains. In both strained and mixed fluids from ½ to ¾ part of sugar is dissolved and then red, unsized rather thick blotting paper, which has previously been printed upon, is drawn through it, allowed to drain and hung up to dry on lines.

Non-freezing Fluids for Central Heating Plants, Machines, etc.—For such purposes glycerine and alcohol are used. A solution of 28 per cent of chloride of calcium in water, which will withstand a temperature of 22 degrees below zero Fahrenheit without freezing and does not attack metals, is cheaper. Other recipe: In 100 parts are contained 1 part chloride of magnesia, 10 parts chloride of calcium, 20 parts chloride of alumina. "Tektrion," a charging fluid for central heating plants, consists of a 25 deg. Bé. solution of chloride of calcium that boils at a little over 212 deg. F. and resists cold of 5 deg. F. For heating plants that are not so liable to be frozen up a chloride of calcium lye of 15 deg. Bé., which resists freezing to 17½ deg. F., may be used. The addition of glycerine to the solution is not advisable.

A molding sand for castings consists of a mixture of finely ground coke and graphite. To insure an absolutely smooth surface to the mold, both substances are intimately mixed and then mixed with melted rosin, whereupon the entire substance is exposed to such heat that the rosin is decomposed, and its carbon residues fill the finest porosities of the coke, while the rosin, in melting, carries the fine particles of graphite with it into the pores. After cooling, the mass is pulverized in edge mills, then ground and screened in a suitable manner. It is advisable to use as little graphite as possible, because the different expansion co-efficients of the two substances may easily cause trouble. A fifth of graphite compared with the whole mass, furnishes the best results, but it is advisable not to be sparing in the addition of rosin; the fluid mixture, before burning, must have the consistency of mortar.

Fluid Bronze.—A liquid non-oxidizable bronze is obtained by mixing bronze color with a neutral solution, free from water, of pure pyroxyline. Where a sufficiently concentrated pyroxyline solution is used the bronze remains suspended in it and does not settle to the bottom. In preparing the bronze proceed as follows: 10 parts of pyroxyline are dissolved in 90 parts of acetic acid ester. With the solution 25 parts of bronze powder are mixed in a color pan or uniformly rubbed down in the color mill. In place of the acetic acid ester we can also use other neutral fluids free from water that will dissolve pyroxyline, notably benzoate, oxalate, or succinate of methyl, or of ethyl, acetic ether, amyl-acetate, camphor, and mixtures of the same. The fluid bronze thus prepared, in addition to the well-known purposes, is specially adapted for use for letter-press and lithographic printing, as well as for tapestry and fabric printing. In the last-named industry it has formerly been customary to bronze by printing with a slow-drying varnish and then dusting the bronze on.

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